VOLUME 49 NUMBER 4

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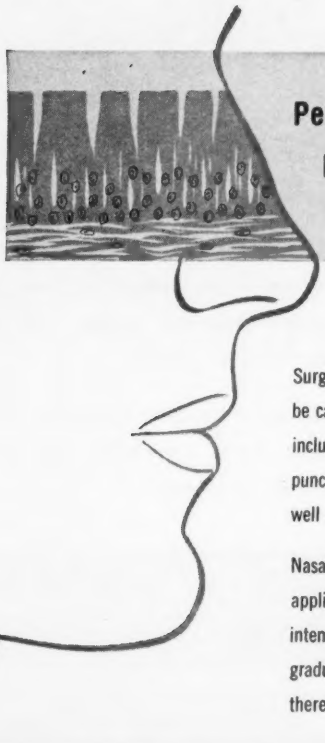

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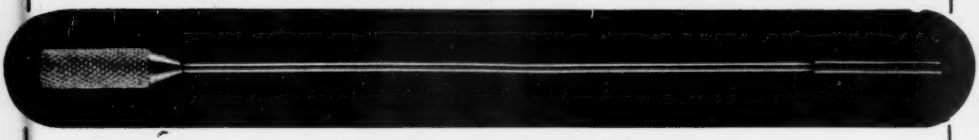

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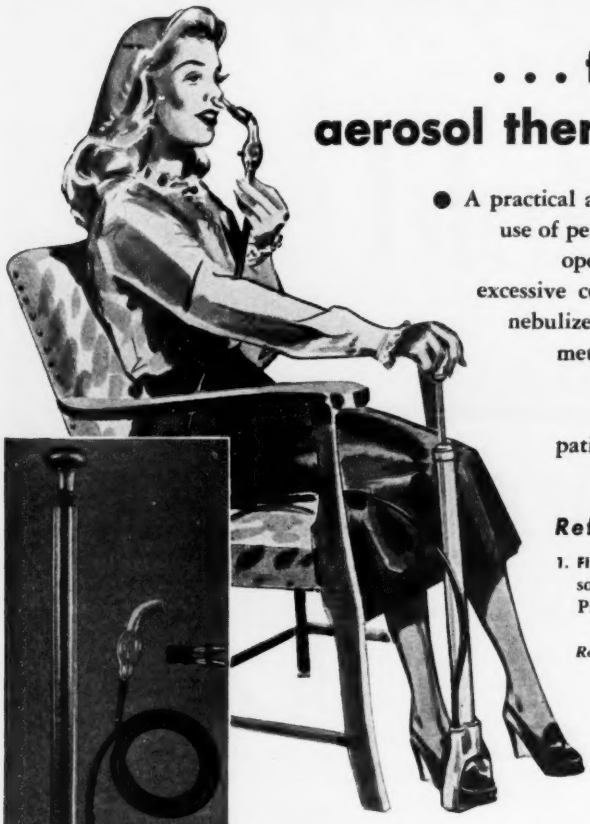

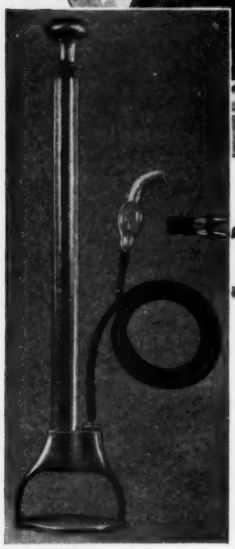

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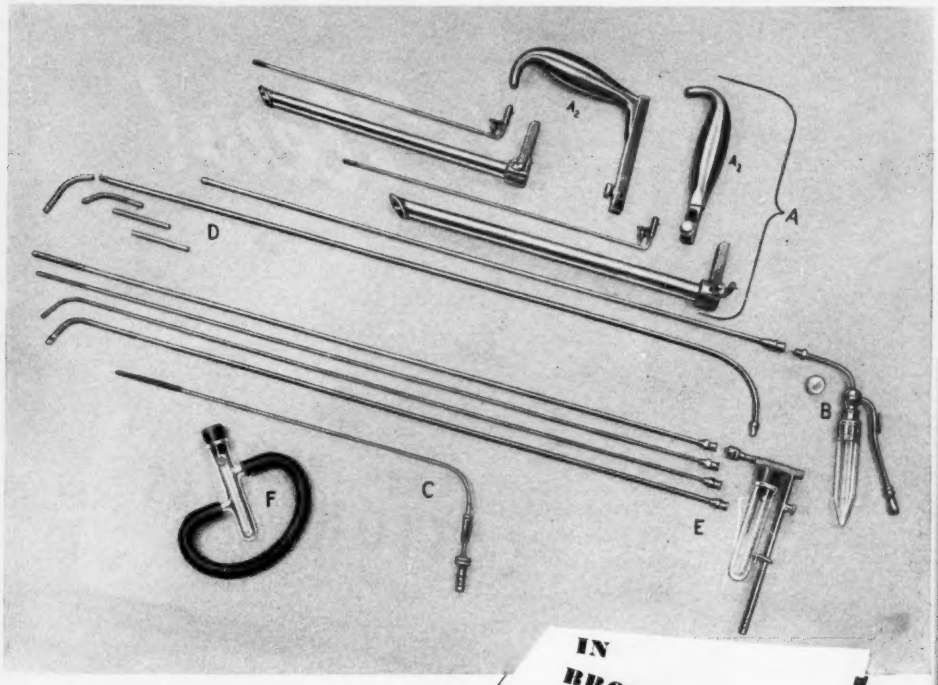

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HYDRODYNAMICS AND HEARING

I. The Operative Relief of Otosclerotic and Nonotosclerotic Deafness and Its Relationship to a Hydrodynamic Hypothesis of Hearing; a Suggested Explanation for (a) the Intimate Association of the Organs of Balance and the Organ of Hearing and for (b) the Function of the Incus

OTTO POPPER, M.B., Ch.B., F.R.C.S. (Edin.)
JOHANNESBURG, UNION OF SOUTH AFRICA

THE DISCUSSION on hearing started four hundred years ago and the argument still continues. It is therefore with some apprehension that any one attempting the reorganization and reorientation of ideas on this subject approaches such a task. That operative procedures have restored hearing in various forms of deafness is now an accomplished fact, and whereas it may at one time have been permissible for theories of hearing tc remain comfortable academic abstractions reserved for physicists and physiologists, Lempert in the last decade has revolutionized the situation. Once otologists are able to restore hearing by operation it becomes essential for them to understand how the human being hears, and theories of hearing may no longer remain in the esoteric sphere.

It is my belief that otologic teaching must be revised and that the hydrodynamic hypothesis offers a satisfying explanation for many phenomena in this complex function.

LEADING QUESTIONS

What Is Meant by Hydrodynamics?—The hydrodynamic conception of hearing postulates certain premises. The stapes is a mobile member which seals the outer wall of the column of perilymph in the perilymphatic sinus of the vestibule. The elastic round window membrane seals the column of perilymph in the scala tympani. These two columns of fluid are completely separated by a gallery—the lamina spiralis ossea with the attached basilar membrane. These fluid columns communicate freely with each other at the apex of this gallery (helicotrema). They thus form a perfect hydrodynamic system—a continuous column of fluid, rigidly enclosed, with mobile sealed ends.

From the Department of Surgery, University of the Witwatersrand, Union of South Africa.

Read before the Section on Laryngology, Otology and Rhinology at the Ninety-Seventh Annual Session of the American Medical Association, Chicago, June 24, 1948.

In a paper published elsewhere [1] I briefly indicated a hypothesis based on hydrodynamics to account for the improvement of hearing following fenestration in otosclerosis.

How Does Fenestration Restore Hearing and Is Such Restored Hearing Normal?—In otosclerosis the stapes is gradually immobilized, the process beginning with limitation of movement and proceeding finally to absolute fixation, and in that event the stapes ceases to function as an escape valve. There is mechanical resistance to pressure. The perilymph is impeded. Its vibrations are no longer allowed free play. They are dammed back and dampened. From these attenuated impulses the organ of Corti receives a correspondingly weaker stimulus, and deafness is established, deafness due in the early phase of otosclerosis purely to the circumstance that a reduced stimulus is reaching a functionally perfect organ of Corti. The latter's potential is unimpaired. It is the stimulus that is at fault.

Clinical otosclerosis is not deafness but a breakdown of the hydrodynamic cochlear system. Stapedial fixation has converted the latter into a tube rigidly sealed at one end. Deafness happens to be the predominating symptom of this breakdown.

To restore hearing, a new escape valve, to remove the mechanical barrier, must be created to restore the hydrodynamic system and to reestablish mobility of the perilymph. Fenestration achieves this—but this only, and no more. The fixed stapes is by-passed and ignored. Fenestration does not, and never can, restore normal hearing. It can restore hearing to or above the serviceable level of the 30 decibel loss. To promise normal hearing would imply restoration of the exquisite function of accommodation. This is irretrievably lost, in any case, in otosclerosis.

The Stapes, the Perilymph and the Round Window Membrane—What Is Their Protective Role?—It has already been shown how the mobile stapes by accommodating the excursions of the perilymph is essential for the normal perception of sound. This accommodation must then be considered as its first function.

One must now consider what happens when the stapedius muscle contracts. Lempert has maintained that the function of the stapes is to protect the cochlea. I would go much further. The following argument is intended to demonstrate that the stapedial apparatus not only directly protects the organ of Corti from injury but guards the whole organism from the peril of surprise attack. Should stimuli or noise be excessive and likely to injure the organ, the stapes is able by muscular

1. Popper, O.: Fenestration of the Labyrinth, J. Laryng. & Otol. **61**:441-458 (Aug.) 1946.

action (the stapedius muscle) to control and adjust excessive excursions of the perilymph or partially to immobilize it. Contraction of the stapedius muscle pulls the footplate of the stapes out of the oval window.[2] This

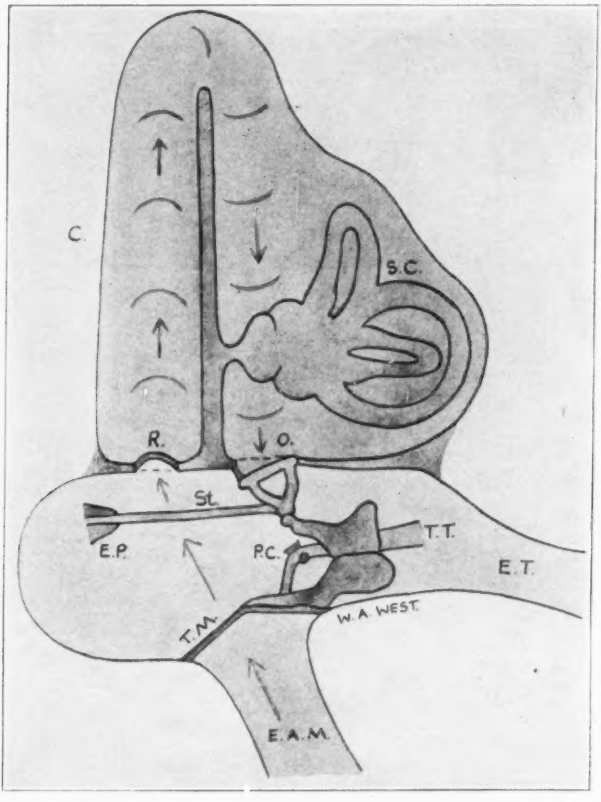

Fig. 1.—Mechanism of hearing. The diagram illustrates schematically how the positive phase of a sound wave acts on the round window membrane: The membrane bulges inward and the stapes hinges outward. *C.* indicates the cochlea; *S.C.*, the semicircular canals; *R.*, fenestra rotunda; *O.*, fenestra ovale; *S.T.*, stapedius tendon; *E.P.*, eminentia pyramidalis; *P.C.*, processus cochleariformis; *T.M.*, tympanic membrane; *T.T.*, tensor tympani; *E.T.*, eustachian tube; *E.A.M.*, external auditory meatus.

2. Sir Thomas Wrightson has shown that the footplate actually hinges posteriorly and, therefore, contraction of the stapedius would pull the footplate out of the oval window.

A hydrodynamic system acts equally well in reverse and for purposes of clarity in the schematic diagrams, contraction of the stapedius is shown to pull the footplate into the oval window.

causes the elastic round window membrane to be drawn in at the opposite end of this hydrodynamic system. The stapes acts as a damper. This dampening protects the organ of Corti from harmful stimulation—an active involuntary cochleostapedial reflex.

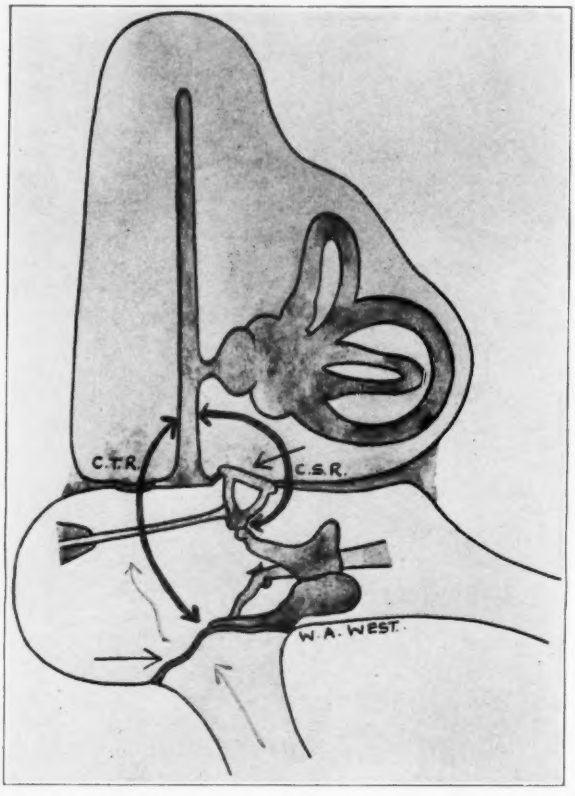

Fig. 2.—Mechanism of protection against excessive sound. The tympanic membrane is relaxed. There is inward movement of the stapes, with a dampening effect on the perilymph to protect the organ of Corti against injury. *C.T.R.* and *C.S.R.* indicate the cochleotympanic and the cochleostapedial reflex, respectively.

Two hundred years ago, Du Verney suggested an attractive theory that the two membranes (the drum and the round window membrane) by varying their tension were capable of increasing the intensity of sounds or a selected portion of the sound spectrum.

It is generally suggested that the ability of a musical ear to pick out instruments in a full orchestra is a central function. Similarly an animal is able to pick out certain portions of a sound spectrum in order to protect itself against the peril of unexpected attack. The devastating conclusion that the musical ear is a throwback, a form of atavism, is inescapable. Bismarck, of the treble voice and black heart, master of

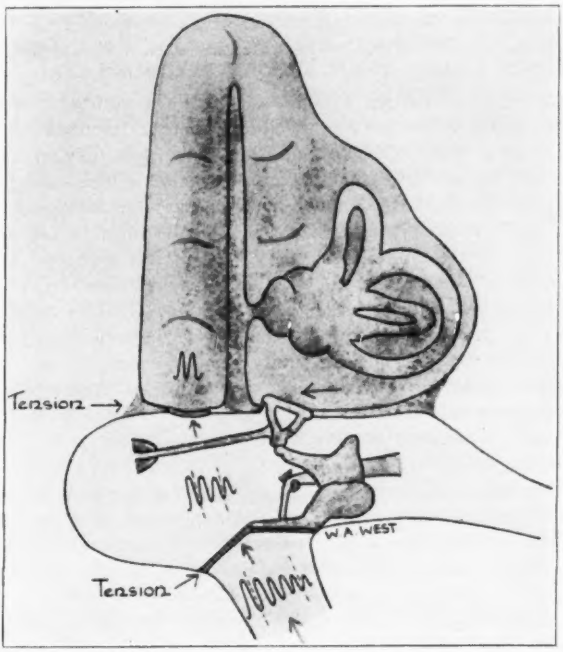

Fig. 3.—Mechanism of selection. The stapes is hinged inward. The round window membrane is tensed outward. The tympanic membrane is tensed by the tensor tympani tendon. Thus a focusing on a selected portion of the sound spectrum is achieved.

intrigue, forger of telegrams, to whom all music was an unpleasant form of noise, would rate high in an evolutionary sense.

> The man that hath no music in himself,
> Nor is not moved with concord of sweet sounds,
> Is fit for treasons, stratagems and spoils;
> The motions of his spirit are dull as night,
> And his affections dark as Erebus;
> Let no such man be trusted—mark the music.

Shakespeare certainly had something there.

Why Are the Organs of Balance and the Organ of Hearing so Intimately Related to One Another?—Every worker in this field sooner or later comes up against the same impasse—to explain the connection between hearing and balance. It seems to me that no compromise is possible until this mystery is cleared up. Embryologists have demonstrated in no uncertain manner that philogenetically these organs belong together and have left it at that. Physiologists and neurologists have diverted their energies in other directions. It is my hope that on the basis of applied mechanics and hydrodynamics this dark corner will be illuminated.

When first confronted with the fact that the vestibular apparatus and the organ of hearing are so closely related, one finds it difficult to understand why two such totally different organs having functions in no way related to each other are suspended in the same medium (perilymph), occupy a common site and share the same endolymph. In the one case the interpretation of movement, direction and position, and in the other the interpretation of sound, is the function. Yet they are intimately connected by the common endolymph, the perilymph and, above all, the cochlear duct, which is an outgrowth from the membranous sacs of the vestibular organ. Ever pursuing the utmost in economy, evolution has designed this contiguity. It is necessary to search for a common denominator of the complex functions as represented by the semicircular canals with their ampullae, the utricle and the saccule which will correlate with properties peculiar to the spiral organ of Corti.

There seems only one fundamental basis for a logical sequence of reasoning. Each one of these organs is designed to measure the most infinitesimal differences of fluid pressure due to movement. The endolymph in the membranous canal by inertia momentum stimulates the receptive organs in the ampullae which interpret movement in the three planes of space. In the case of the utricle and the saccule, gravity bends the hair cells loaded with their otoliths in one or other direction, and thus they interpret the position in space of the body at rest. Infinitesimal pressure effects determine the position of the body both in motion and at rest, and also give rise to protective postural reflexes. In the case of the spiral organ of Corti the same principles apply, and it also responds to minute differences of fluid pressure due to movement. Whereas the stimulus in the ampullae of the canals (inertia force) and in the utricle and the saccule (gravity) may be called a continuous pressure, in the case of the cochlear organ the pressure stimulus changes its magnitude and direction in a periodic manner. In man the cochlea is able to interpret pressure periodicities varying from 16 to approximately 30,000 cycles per second, which covers the human sound spectrum. A common denominator is thus established for the entire labyrinth

as the interpreter of minute differences of pressure, continuous or periodic, and the contiguity of the organ of hearing and the organ of balance becomes comprehensible. It will be noted that in the case of the vestibular apparatus it is the endolymph and not the perilymph that stimulates the ampullae or the sacs. The perilymph acts merely as the suspensory medium for the membranous vestibular organ. In the organ of hearing, however, the perilymph is made use of for an entirely different purpose. Here it acts as the transmitting medium for the sound impulses and the whole mechanical arrangement of the cochlear apparatus is so adapted as to permit it to perform this function. For such free movement to occur the receptive organ of Corti must be disposed in a suitable mechanical system to allow of the fluid reciprocal excursions around it. Only a continuous tube each end of which has a freely mobile member will permit this—a hydrodynamic system. The cochlea is such a hydrodynamic system. It consists of two tubes, the scala tympani and the scala vestibuli, communicating at the apex (helicotrema). The column of perilymph is thus continuous. The endolymph within the cochlear duct does not of itself initiate pressure differences. These are transmitted to it by the excursions of the perilymph.

A PERTINENT COMPARISON

Before submitting a patient to the Smithwick operation, one would want to know, first, why this procedure reduces blood pressure and, second, its scope and limitation. In order to check exaggerated and absurd claims regarding improvements of hearing following fenestration a similar attitude seems imperative. The question "How do we hear?" can no longer remain a comfortable academic abstraction. A controversy which began in the sixteenth century must therefore be revived and revised.

HOW MAN HEARS: FUNCTION OF THE OSSICLES

The fact that the three ossicles have always been referred to collectively as a "chain" is nothing short of a calamity. The very term by subconscious association is an insistence that they act together as a link. Whereas, in fact they have each an individual function and indeed are individually derived from different sources. The malleus is developed from Meckel's cartilage. The incus is derived from the quadrate cartilage, and the whole hyoid arch goes into the development of the stapes, which should have given otologists a clue of its enormous importance. That separate origins should indicate separate functions seems an inescapable conclusion, and yet search through current literature fails to illuminate these functions.

Stapes.—The functions of the stapes have already been considered: (1) to accommodate excursions of the perilymph in hearing and (2) to

create differences of pressure between the two windows (*a*) for the protection of the organ of Corti against injury and (*b*) for the protection of the whole organism.

Incus.—Excursions of the stapes are exquisitely adjusted by the tendon of the stapedius muscle, which is inserted into the neck of the capitulum above the relatively long crura as these dip down to be attached to the footplate. Nature aims at lightness, leverage and mechanical efficiency.

With this leverage the infinitesimal and equisitely delicate excursions of the stapes would be impossible to control if the capitulum were not kept in the same plane of movement. The muscular force is applied relatively far away from the footplate. Were the latter to cant or twist

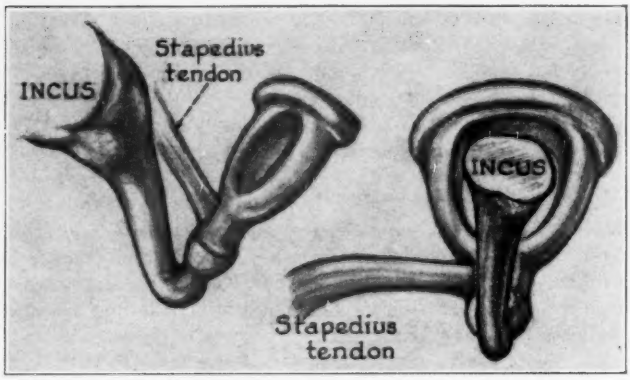

Fig. 4.—Function of the incus. This shows how beautifully the lenticular process of the incus is adapted to center and poise the capitulum of the stapes.

one way or the other, adjustments within such minute limits would be out of the question. It is essential that the capitulum of the stapes be permitted to move only in one plane. The lenticular process on the long crus of the incus insures this. By its elastic attachment, it centers the capitulum of the stapes and limits its movement within that plane. Clearly, then, the radical mastoidectomy that indiscriminately removes this ossicle irreparably injures the mechanism of hearing. The capitulum must remain delicately poised and centered.

Another function of the incus is to support the articular surface of the head of the malleus (see later paragraph). A third function must now be considered.

The incus, by its elastic attachment to the capitulum of the stapes, opposes the tonic action of the stapedius muscle. No other balancing

mechanism exists which would prevent the stapedial footplate from being pulled out of the oval window. This would dampen vibrations of the perilymph and cause deafness.

Clearly, unopposed action of the stadepius muscle is in the highest degree undesirable. The sacrifice of a healthy incus is unthinkable. Yet, using the gentlest manipulation and exercising the greatest possible care, the surgeon often sees this happen in the radical mastoidectomy. The attachments of this ossicle are fragile.

To prevent irreparable permanent deafness when the incus has been removed and the stapes is mobile, contraction of the stapedial muscle must be prevented. The surgeon must therefore divide the stapedial tendon—a labor of a few seconds—so that hearing is preserved.

It has been shown experimentally that the stapes will vibrate with twice or even three times the amplitude after the tendon has been cut.

The stapes is then free to accommodate perilymph excursions but is no longer capable of dampening the perilymph to protect the cochlea against injurious noise or to adjust the tension of the round window membrane to filter out unwanted portions of the sound spectrum.

The functions of the incus may be summarized thus:

(1) To poise and center the capitulum of the stapes so that movement caused by contraction of its muscle will be restricted to a prescribed orbit or plane

(2) To oppose the tonus of the stapedius muscle and prevent the permanent deafness that would result if the footplate were pulled out of the oval window, with resultant dampening of the perilymph

(3) To support the articular surface of the head of the malleus

Malleus.—The function of the malleus is obvious. It adjusts the tension of the tympanic membrane by action of the tensor tympani muscle.

A SURGICAL CLASSIFICATION OF CASES CONFORMING WITH THE HYDRODYNAMIC HYPOTHESIS

The foregoing pages, as indicated by the title, form only a part of the "Introduction to the Hydrodynamic Hypothesis." Experimentation and research are continuing. Further communications will appear in due course when sufficient material has been collected. Such material—especially results bearing on the operative restoration of hearing in cases of hypotympanic deafness—should be available from all centers where the transtympanic approach is carried out.

The transtympanic approach described elsewhere in this issue is ideally suited for the clearing of the hypotympanum with minimal trauma. A practical surgical classification suggests itself when operative measures are resorted to for the restoration of hearing in conformity with the

hydrodynamic hypothesis. When the opening at the oval window end of the system is the cause of deafness, as in otosclerosis, the fixed stapes sealing the oval window, the condition, in this surgical classification, would be called (1) *stapedial deafness;* obstruction to sound reaching the round window region would be termed (2) *hypotympanic deafness,* and to both of these groups must be added (3) *irreversible deafness* when irreversible changes in the cochlear organ indicate degeneration.

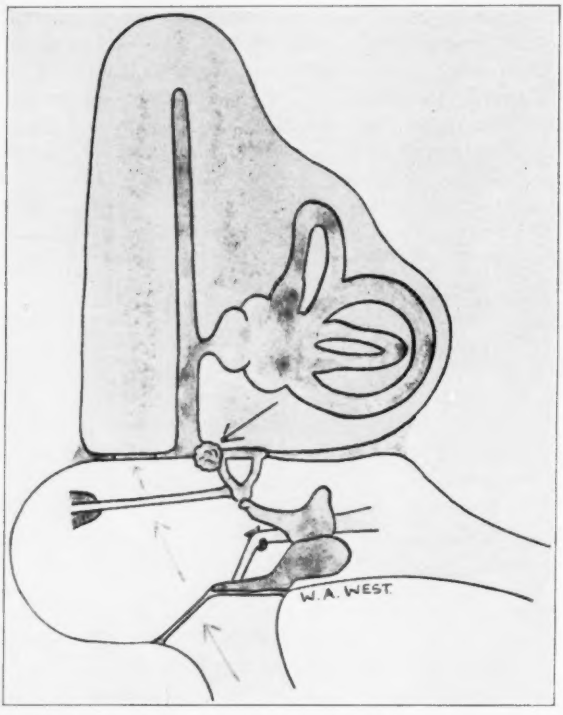

Fig. 5.—Mechanism of sclerotic deafness. The hydrodynamic system has been destroyed. An inward excursion of the round window membrane is impossible. The perilymph is static. (An attractive hypothesis, as yet without any experimental corroboration, suggests itself to account for paracusis willisiana. The perilymph is now a "silent" pool in a closed system. Where both windows are mobile, the perilymph is in a constant state of movement or turbulence. In order to produce any movement of the static perilymph, the inertia of rest must be overcome; therefore, sound must be of sufficient amplitude to overcome such inertia and to have, in addition, sufficient reserve to excite the organ of Corti. Where the perilymph is already in motion, as it would be when the otosclerotic patient is in surroundings where vibration is transmitted through the skeleton, a lesser stimulus would possibly suffice, as the inertia of rest has been overcome by the external vibration.)

In this paper evidence has been led to support the view that the round window is part of the sound pathway. It has further been shown that the deafness of otosclerosis is due to a breakdown of the hydrodynamic system. In otosclerosis the sound stimulus is ineffective despite a clear sound path (the round window) and an unimpaired organ of Corti. The exit portion of the system is sealed. Otosclerosis is not deafness but a breakdown of the hydrodynamics in which deafness is the predominating symptom. By creating an opening in the exit limb of

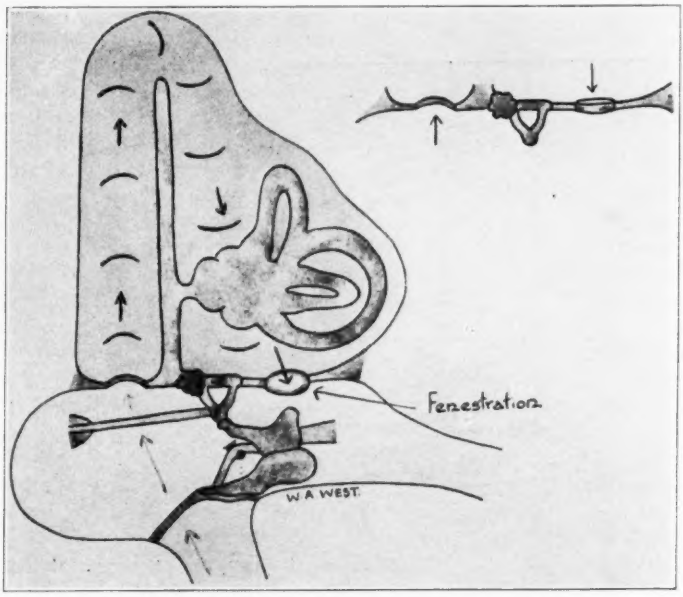

Fig. 6.—Restoration of hearing by fenestration. With creation of an escape valve, the round window membrane bulges inward with the positive phase of the sound wave. The detail at the upper right illustrates the effect of the Lempert cartilage stopple. The cartilage, acting as an escape valve, prevents direct stimulation of the perilymph. The elasticity or mobility of the cartilage accommodates perilymph excursions. There is normal entry of sound through the round window.

this system—fenestration of the vestibule—the cochlear apparatus again functions as a hydrodynamic system, and hearing is restored.

CASES OF HYPOTYMPANIC DEAFNESS

This is a vast group in which hearing by air conduction has become impaired in consequence mainly of chronic otorrhea and suppuration, the impairment being directly due to the accumulation of granulations,

polyps, fibrous tissue or hyperplastic processes which obliterate the hypotympanum and the region of the round window. A series of patients were operated on for chronic suppuration and deafness. Each had a densely sclerosed mastoid process, and the infection was confined to the attic. Bone conduction revealed that the organ of Corti was relatively unimpaired. This established the correctness of the assumption that the loss of hearing was due to inability of sound to penetrate the

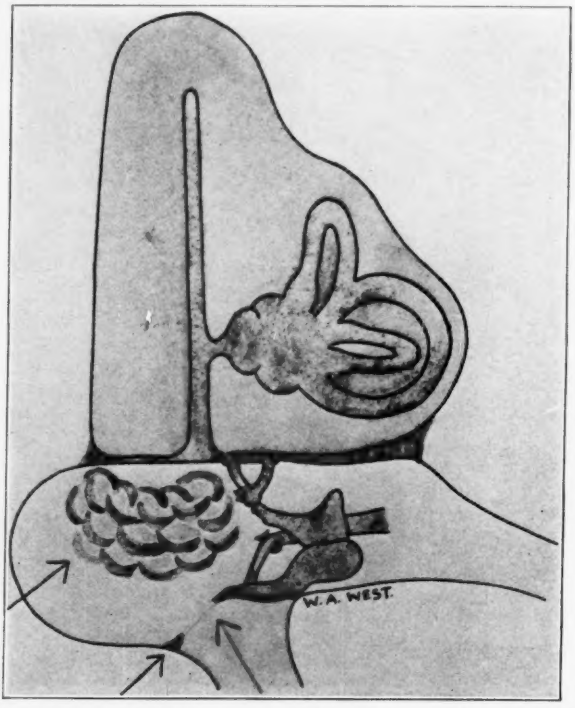

Fig. 7.—Transmission deafness. The diagram shows a cushion of hyperplastic tissue, polypi or granulations in the region of the round window occurring with a tympanic defect. The hydrodynamic system is unimpaired, but sound impulses cannot reach the round window membrane; the perilymph is static; therefore, these patients have paracusis as well as deafness.

cushion of tissue overlying the hypotympanum. In this condition, unlike otosclerosis, the hydrodynamic system is intact and the stapes is mobile but the organ of Corti is isolated and inactive because the sound impulses are prevented from reaching it by the obstruction at the entry of this system. Such a condition, therefore, has been termed hypotympanic deafness.

In 27 cases the transtympanic technic was employed to clear the attic and the hypotympanum. The densely sclerosed mastoid process was left untouched, and the ossicles were preserved when possible. When it was not possible to preserve the incus, the stapedial tendon was divided (in 5 cases). In 7 cases the disease had involved the incus; its lenticular process had been destroyed and the capitulum of the stapes could not be identified. With the transtympanic technic, exposure of the round window region presents no difficulties whatsoever. In every one of these cases the hypotympanum was carefully cleared of every vestige of granulation, polyp or hyperplastic tissue until the fossula of the round window was completely exposed. The entire attic was cleared of all infected bone right up to the tegmen tympani. Great care was exercised to preserve the incus, whose function has already been indicated in this paper. Eighty per cent of the patients exhibited a dry ear within three weeks. The same percentage had an immediate postoperative hearing improvement that amounted almost to normal hearing. This was spontaneously commented on by these patients and was a most gratifying result. It must be remembered that in cases of chronic hypotympanum deafness the patient is accustomed to regard the ear as useless and the organ has been written off for years as functionless. Any improvement that may result from the operation comes in the nature of a dramatic surprise.

With the revision of conceptions of hearing, and more particularly with reference to the hydrodynamic hypothesis, the time may have come when otologists will not longer regard the hearing in the "chronic ear" as "written off." Much research and investigation still must be done before a standardized technic will crystallize. In only 4 of the series of patients mentioned has this hearing improvement been maintained. Despite cessation of discharge, a gradual heaping up of tissue in the hypotympanum once again has obliterated the round window region, and with this the hearing has returned to the preoperative level. Despite this meager result, it is my conviction that the day is not far off when with the concerted help of otologists all over the world a method will emerge which will effectually keep the hypotympanum clear. Otology is on the threshold of such events.

In carrying out operative procedures on infected ears one should have due regard to the function of the ear: The discharge, which is secondary, should remain secondary and be controlled. With the development of equipment and with that which today exists enabling the microsurgery of the tympanum to be executed under perfect visual control, one may say that one's first aim is that the ear shall hear.

The round window lies in a cul-de-sac surrounded by the following blind end extensions and protuberances: the sinus posterior tympani, the eminentia pyramidalis, the sinus tympani, the cavum tympani, the

subiculum promontorii, the sulcus promontorii, the fossula fenestrae cochleae and the cellulae tympanicae. Any infective condition of the middle ear may lead to partial or complete obliteration of this vital air space.

In acute otitis media, happily, adhesions are rare, and resolution leaves this air space intact—and hearing unimpaired. Not so the chronic conditions: chronic otitis media suppurativa, chronic otitis media non-suppurativa (chronic adhesive catarrh), osteitis, granulations, polypoid degeneration and cholesteatoma.

Radical mastoidectomy itself is largely instrumental in destruction of hearing. Operative trauma is followed by deposition of fibrous

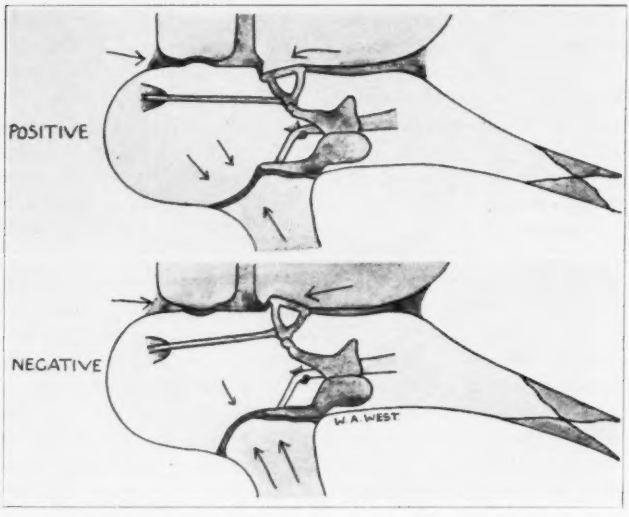

Fig. 8.—Mechanism of eustachian deafness. The dampening effects of positive and negative differences of pressure are shown: Positive pressure in the tympanum pushes the round window membrane inward, whereas negative pressure pulls it outward. In both cases dampening is produced, and the organ of hearing is thrown out of equilibrium, with resulting deafness. This accounts for the sensation of deafness experienced both in ascending and in descending in airplane travel, when air pressure in the middle ear is not in equilibrium with outside air pressure. The eustachian tube is closed.

tissue or granulations which obstruct the round window vestibule. In the conventional fenestration operation, radical mastoidectomy is the preliminary step. When a hearing gain is not maintained after fenestration despite a positive fistular sign and an open fenestra, I am convinced that the obstruction to sound transmission is fibrous or granulation tissue deposited in the round window cul-de-sac. The surgeon has

relieved the stapedial deafness and has created hypotympanic deafness. This area must, therefore, be treated with the greatest respect in the conventional fenestration operation in which mastoidectomy precedes the actual fenestration stage.

In transtympanic fenestration such interference of the hypotympanum does not arise. The transtympanic operation is entirely supratympanic, and the mastoid is untouched. To restore hearing in cases of hypotympanic deafness the piece of tissue, fibrous, polypoid or granulated, or the thickened drum that forms the barrier at the round window must be removed.

Hypotympanic deafness may be defined as a condition in which sound of normal amplitude or intensity is incapable of penetrating this barrier to excite the perilymph adequately to elicit a cochlear response.

If the thick mechanical barrier to hearing could be removed and replaced by thin epithelium, then it might be claimed that another vast group of persons suffering from deafness has been brought within the orbit of operative relief. In the war on deafness, this must be the next objective. Its conquest may be hastened by transtympanic surgery.

Prof. George von Bekesy, research lecturer at Harvard University, director of the Institute of Experimental Physics, Budapest, Hungary, gave guidance and help in the drafting of this paper, and Prof. M. H. Lurie, of Harvard University, contributed sound advice.

Fifth Floor, Lister Building.

TRANSTYMPANIC APPROACH AND FENESTRATION

II. The Current Technic

OTTO POPPER, M.B., Ch.B., F.R.C.S. (Edin.)
JOHANNESBURG, UNION OF SOUTH AFRICA

THIS WORK was first published some two years ago in Great Britain and South Africa. Since then the transtympanic approach has been accepted and adopted in various overseas centers. This paper will endeavor to present in detail some refinements of technic. Needless to say, in any progressive science nothing is really final, and further refinements are sure to be incorporated as and when an ever larger number of surgeons perform this logical procedure. It becomes, however, increasingly necessary once more to state clearly the objectives and the scope of the transtympanic approach.

The transtympanic approach has nothing whatsoever to do with fenestration. Fenestration happens to be a procedure for which this approach is eminently suitable. As will be shown later in this address, the transtympanic approach is ideal for the performance of an atticoantrostomy when the mastoid process is sclerotic and the infection is confined to the atticoantrotympanic region, as an alternative procedure to the radical mastoidectomy, endaural or postaural.

The Lempert fenestra nov-ovalis operation consists of two classic procedures, the Lempert endaural mastoidectomy and, superimposed on it, the Lempert fenestration.

Transtympanic fenestration is also a dual procedure—the transtympanic approach followed by the Lempert fenestration.

The Lempert endaural mastoidectomy is the ideal operation for chronic mastoiditis plus attic suppuration.

The transtympanic approach would supply perfect drainage of the atticoantral region only and is indicated when the mastoid process is sclerosed but uninfected.

Douglas C. Carruthers, of Sydney, Australia, who has considerable experience both of the endaural and of the transtympanic operation states:

> I am attracted to the transtympanic method because of its simplicity and because the access obtained is so much more direct than any other approach. With regard to the results of fenestration where this approach is used, an

From the Department of Surgery, University of the Witwatersrand.

Read before the Section on Laryngology, Otology and Rhinology of the American Medical Association, Chicago, June 23, 1948.

improvement of hearing comparable with that of any other method can be achieved by the transtympanic approach. I would stipulate, however, that much as one may have operated by other methods, an attempt at a new approach is not always easy. Just as otologic surgeons have had to prepare themselves for the endaural method by assiduous and oft repeated cadaver practice, so they must do this again before it is reasonable to expect that they will correctly assess the new method. The surgeon who will just try the transtympanic approach once or twice, and be turned back by its little difficulties rather than master them, will, I am sure, deprive himself of much of the pleasure which comes of being able to orientate oneself to a new surgical environment. I still operate by both Lempert's and Popper's approach, and I have many technical points which are my own. I am not prepared to say yet that one method is entirely better than the other. The main significance of Dr. Popper's work, as I see it, is that he has devised a simple and practicable anterior transmeatal approach to the posterior portion of the tympanum, the aditus and the vestibulo-ampullary area. As such, I am sure that it will be of lasting use in otologic surgery.[1]

Only after assiduous cadaver practice will the surgeon be capable of deciding this issue for himself. Revisions are difficult with this approach, and the Lempert procedure is recommended. When fenestration is to be performed in the presence of a sclerotic mastoid process or an abnormal lateral sinus, the transtympanic approach seems the method of choice.

The transtympanic approach was devised some five years ago. The objective was to provide the more direct, as well as the widest, exposure of the attic region, aditus and antrum. When one goes over in one's mind what constitutes the main indication for radical mastoidectomy, it seems fair to say that the answer is chronic suppuration of the attic. Another observation that cannot have escaped any one is that most chronically discharging ears, probably 90 per cent, exhibit dense sclerosis of the mastoid process on roentgen examination. This deposition of bone is nature's method of reacting to an infective process—her attempt to prevent its extension. Why, then, when the infection is limited to the attic space, does the surgeon as a matter of routine reopen the sclerotic mastoid? The reason is that he is required to create a tunnel which will lead to the attic—or, in other words, he does a radical mastoidectomy, either modified or varied to suit his individual taste, in order to make the attic space communicate with the external auditory meatus. The bone thus exposed is prone to a low grade reinfection, and although the surgeon has drained the

1. The Lempert technic gives magnificent exposure as well as entry and maneuvering space, and no surgeon not thoroughly familiar with this technic should attempt the transtympanic approach with its new orientation and environment. With proper equipment, experienced surgeons will have not the slightest difficulty in carrying out the less traumatic transtympanic operation for adequate exposure of the attic, the antrum and the site of fenestration, but entry and maneuvering space are admittedly not so wide. This is not too high a price to pay to preserve the mastoid process.

suppurative focus in the attic, he is too frequently faced with a troublesome and often stubborn postoperative otorrhea.

To be able to gain wide exposure of this region without traversing the mastoid process seems imperative, and this is amply achieved by the transtympanic approach. Needless to say, when the mastoid process is not sclerotic, mere drainage of the attic is insufficient, and it may be necessary to do a postaural or an endaural exenteration of the infected mastoid cells in addition to the drainage of the epitympanum or attic.

The great virtue of the transtympanic operation is the preservation of the skin of the meatus. The meatus is the corridor already beautifully lined with skin, which remains undisturbed.

The advantages of the transtympanic approach whether used for drainage of the atticoantral region or for fenestration may be briefly summarized: 1. It is a direct frontal attack on the atticoantral region—the ideal fenestration site. 2. The mastoid process is untouched. 3. The site of fenestration lies square on, and by working from this anterior point of vantage a larger fenestration can be achieved. 4. The membranous labyrinth is seen to better advantage through the operating microscope. 5. Trauma and postoperative otorrhea are minimal. 6. The field is bloodless. 7. The operating time is reduced. 8. The tympanomeatal flap is fashioned right at the outset of the operation, before any burrs are used and bone dust and particles created. The flap is immediately tucked away safely under the ledge of the tympanic plate. Its osteal surface is covered with a protective piece of guttapercha, and the entire space under the ledge of the tympanic plate is packed off with cotton wool pellets. The flap can then be forgotten, safe from trauma and fouling by bone dust to the end of the operation.

The fact that this flap can be fashioned so easily and within a few minutes has evoked much favorable comment. This feature alone, it is claimed, would determine the permanent position of the transtympanic approach in operative otology. It might be useful to mention at this juncture that the tympanomeatal flap can be fashioned in any way the surgeon desires. In the fenestration procedure it must hinge from the annulus tympanicus at the upper border of the tympanic membrane. In atticoantrostomy it should preferably hinge from an outer portion of the canal. This flexibility will be greatly appreciated by surgeons familiar with this type of surgery. Using the transtympanic approach, one does not find it necessary to remove the head of the malleus, and reports from other workers, including Shambaugh, Juers, Tato and Lund, have confirmed that postoperative results are thereby in no way prejudiced.

POSITION OF THE PATIENT

Custom dies hard. For over half a century every aural surgeon has been taught to approach any structure of the ear through the mastoid process and, accordingly, he operates from the back. It is not sur-

prising, therefore, that many surgeons have attempted to do the transtympanic operation from the back despite explicit instructions to the contrary. I have heard numerous protests that the large exposure of attic and clear landmarks that I described were unattainable and that the operation was found most difficult and access restricted. In the case of every single one of these protests it transpired that the surgeon attempted this operation by standing behind the patient in the conventional manner. It must, therefore, again be repeated and emphasized that the surgeon operates from the front; the patient faces him with the ear to be operated on uppermost, and it is essential that these relative positions of the patient and the surgeon be maintained from start to finish. The *raison d'être* of the transtympanic operation is that it is a frontal attack. It is impossible to carry out this technic from the back.

ILLUMINATION STEREOSCOPY AND MAGNIFICATION

In a previous publication the importance of stereoscopic illumination and of magnification was stressed, and it was explained why competent headgear incorporating perfect beam illumination and stereoscopy, and adequate magnification, was so essential. With the wider exposure in this final technic the conventional Lempert equipment may be used. I nevertheless favor the prismatic headgear.[2] The advantage of having an intense beam of light near the same plane as the optical axes must be experienced to be appreciated.[3]

CASE RESULTS

With every improvement in technic the improvement in the results to date has been most striking. Simson-Hall recorded that, of a series of 200 cases, only half were suitable for analysis. This has also been my experience in a smaller number of cases. Changes of technic,

2. Popper, O.: Fenestration of Labyrinth: II. Transtympanic Fenestration, J. Laryng. & Otol. **61**:441-458 (Aug.) 1946.

3. During a recent visit to the United States at the invitation of the American Medical Association, the author had lengthy conferences with leading manufacturers of optical equipment. When this headgear eventually becomes available, the features stressed will be incorporated, that is, light beam near the optical axis; very short interpupillary distance at the objective surfaces of the prisms insuring constant and perfect stereoscopy; two stage magnification from 1.5 to 2 up to 3 and 3.5. The surgeon will wear this headgear from beginning to end of operation without interchanging and will be able to use one or other of the magnifications at any stage of the operation by moving a sterilized lever. This headgear would be equally useful to ophthalmic surgeons. A working distance of between 9 and 11 inches (23 and 28 cm.) using the Galilean system of magnification is the aim. The makers will supply this headgear in a suitable case with a sturdy lock. Correction for the surgeon's error of refraction will be incorporated, so that he will not be required to wear spectacles. This banishes the nuisance of fogging.

inadequate follow-up (a great handicap in a large country such as South Africa, where huge distances separate sparsely populated communities), poor selection, inadequate equipment, cases early in the series and cases too recent for appraisal account for the omissions which reduce the number to less than half. Fenestration has restored hearing to or above the 30 decibel level, with hearing gains of from 12 to 25 decibels

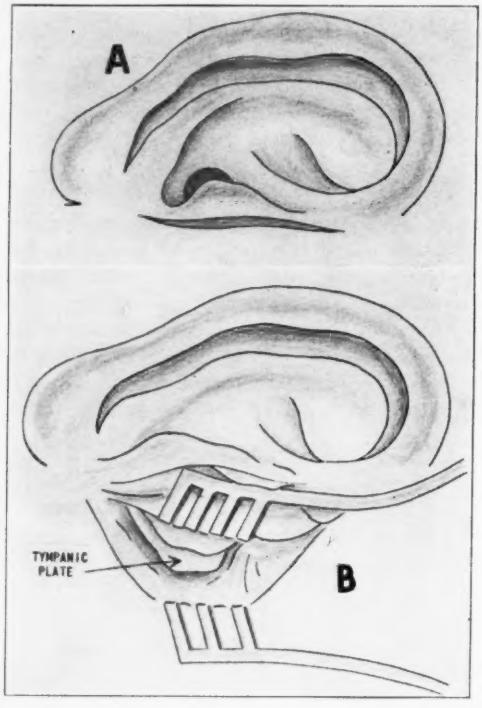

Fig. 1.—Stage 1. In *A* an excursion is made into the fascial plane of the temporomandibular fossa. In *B* the tympanic plate is exposed.

for the frequencies 512, 1,024 and 2,048 cycles per second in 74 per cent of cases which would be regarded as of class A. This improvement has been maintained on an average for about one year, and a review at a later period will demonstrate whether or not the result is permanent. In other cases in this series there was recorded a gain of less than 10 decibels, and this did not bring the hearing level to the 30 decibel line. In still other cases, with hearing gains in some instances of 30 or more

decibels, the improvement was lost, and the hearing sank to the preoperative level. In all cases the audiograms were made in an external center. I am aware that this record may not be impressive when

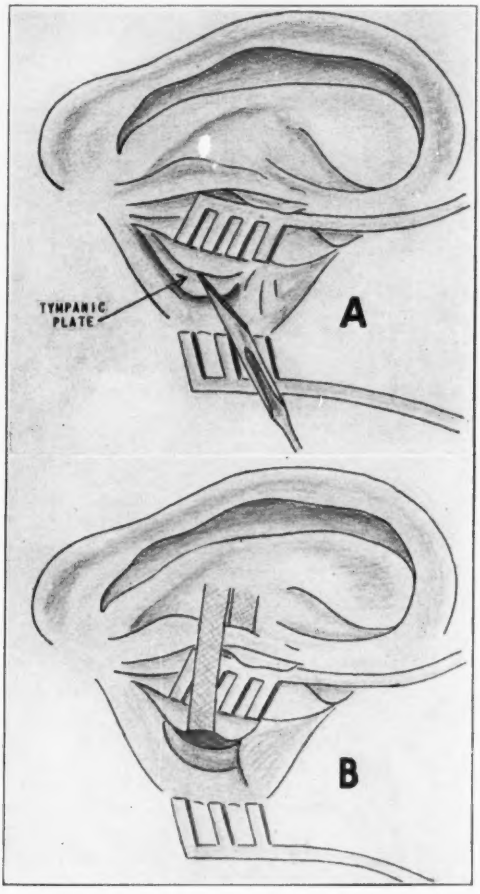

Fig. 2.—Stage 2. In *A* the inferior and superior edge of the meatal cartilage is being detached. In *B* the free edge of the cartilage is being everted.

compared with some that have been published, and it is my hope that with more experience and many other surgeons now using the transtympanic approach, those records of achievement will be equaled. In

one case hearing was destroyed because of detachment of the flap. In another the facial nerve was injured. In this case the fenestration was too near the facial canal and had encroached on the upper surface

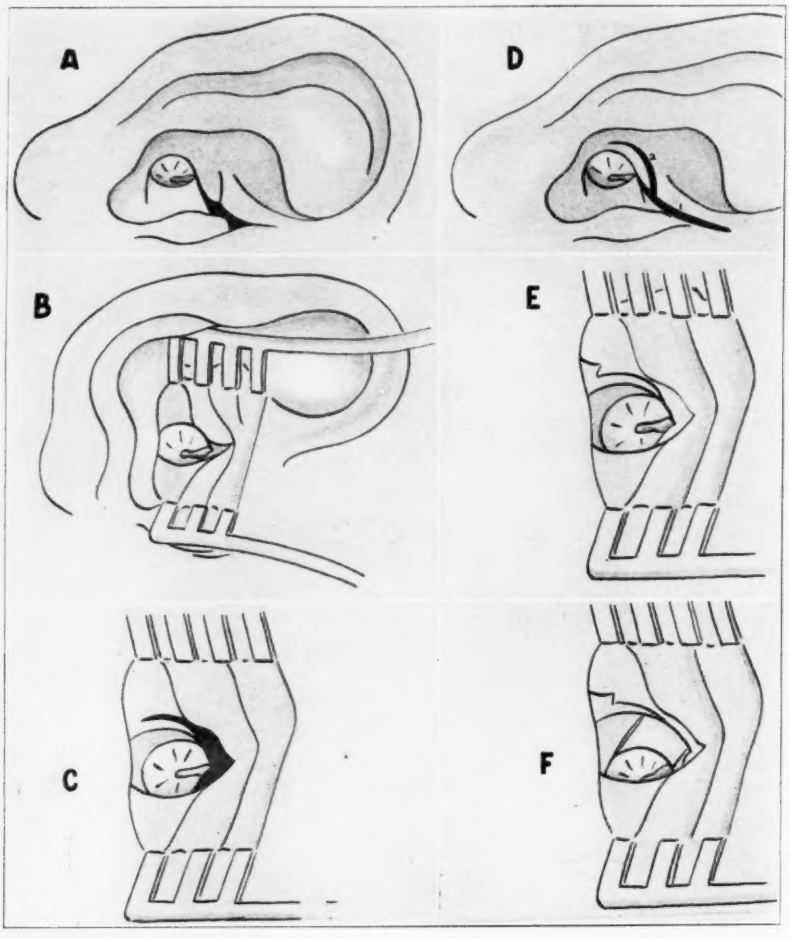

Fig. 3.—The alternative endaural incision: *A*, first incision at 12 o'clock; *B*, retraction; *C*, second incision made during retraction; *D*, both incisions undistorted (without retraction); *E*, posterior L flap and anterior flap retracted to expose the bony meatus, the mastoid cortex and the root of the zygoma. *F*, same as above plus tympanomeatal flap incisions.

of the canal, tearing the blood vessel which is constantly found at this level of the canal. When one is performing fenestration, all such hazards must be kept in mind, and although the final technic virtually

banishes them, the patient must in every instance be fully enlightened. It is my practice to explain these hazards in detail to the patient and to insist on his signing a statement that the hazards have been explained to him and that he has understood them.

The technic about to be described is practiced with great success, notably by Lund and Aubry, whose statistics of successful results in class A cases compare favorably with results elsewhere. They have to their credit a very much larger number of cases than it would be possible to collect and present in a country with such a small population as South Africa, and it is on the results of such overseas workers rather than on my own work that the final evaluation of the transtympanic operation will rest.

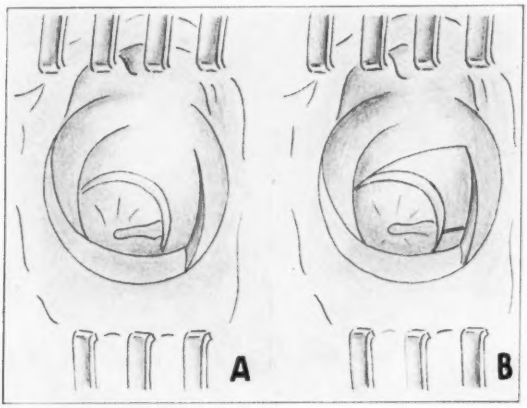

Fig. 4.—Stage 3. In *A* the tympanic membrane is seen lying at the bottom of the external auditory meatus. In *B* the tympanomeatal flap is mapped out.

ANESTHESIA

Any of the conventional methods of inducing local or general anesthesia may be employed. In the case of the latter, however, the anesthetist is to be instructed to avoid congestion. The choice of anesthetic is therefore largely a matter of the surgeon's preference. I have operated recently in South America with the patient under local anesthesia and found it entirely adequate.

PREPARATION OF PATIENT

It is preferable to admit the patient to the hospital at least thirty-six hours before the operation, and one may administer sulfadiazine during this period. The ear to be operated on is prepared in the usual way. The position of the patient has been stressed; the surgeon operates from the front, with the patient's face directed toward him. If, therefore, the right ear is to be operated on, the head rests on the left side, preferably inclined somewhat downward.

THE FINAL TECHNIC

STAGE 1.—*The Temporomandibular Fossa Is Entered and the Tympanic Plate Exposed.*—In the first stage of this operation one makes an excursion into the temporomandibular fossa in the fascial plane immediately contiguous with the cartilage of the tragus and of the external auditory meatus. This area is infiltrated with a 1 per cent procaine hydrochloride solution containing 8 drops of epinephrine hydrochloride solution to the ounce. The first puncture is made about 1 cm. in front of the tragus, the point of the needle being directed backward toward the cartilage of the tragus but only up to and not through the cartilage. The needle is withdrawn slightly and the fluid injected. By directing the needle through this one puncture upward, downward and inward and continuing the injection at each stage, this entire space is infiltrated. By careful manipulation, hugging the cartilage, one is generally able to get the point of the needle onto the tympanic plate, where further infiltration proceeds.

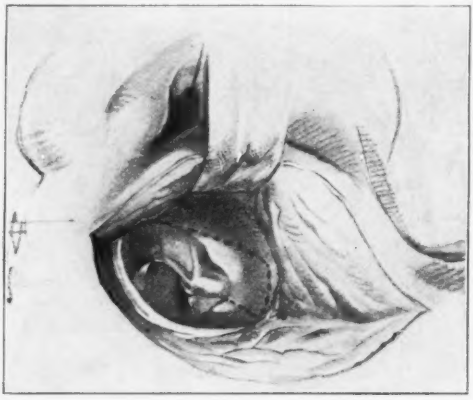

Fig. 5.—Realistic illustration of the outlining of the tympanomeatal flap.

It might be mentioned at this stage that the temporomandibular articulation is remote and that throughout this operation there is not the slightest risk of injuring it. Not a single symptom referable to this region has been encountered in over 100 cases. The articulation is 13 mm. from the external auditory meatus! The first stage of this operation is illustrated in figure 1.

An incision running from the lobule to the helix approximately 1 cm. in front of the tragus and about 3 cm. in length is made, with the blade of the knife being directed toward the cartilage of the tragus. The blade must not go through the cartilage; it must go only up to it. The edges of the incision are separated with an ordinary mastoid retractor, and bleeding points are secured. This first stage embraces exposure of the tympanic plate. The cartilage of the tragus is defined in the posterior part of the field now exposed and, with the blunt handle of the knife, cleared as far down as the tympanic plate. Occasionally, small fibers anchoring the perichondrium to the overlying fascia are snipped with ophthalmic scissors. It will be noted that a sharp angle is present in the cartilage of the tragus where it dips backward to become the cartilage of the

external auditory meatus. When this region has been cleared, it is advisable to remove the retractor and reinsert it so that the blades engage below this angulation. Again careful blunt dissection is carried out toward the meatal cartilage in all directions, that is to say, from below upward and also superiorly where the tongue of meatal cartilage becomes attached to the superior bony wall of the meatus. The latter point is of great importance. It is one of the modifications in this new technic to detach the meatal cartilage both from the tympanic plate and from its attachment to the superior bony meatus. This insures the eventual magnificent exposure of the tympanic field. Blunt dissection is proceeded with until the edge of the tympanic plate is felt on the dissector or a probe. The dissector sweeps from below upward and from before backward so as to free the entire meatal cartilage. After removing and reinserting the retractor somewhat deeper, the entire tympanic plate is exposed to view and the first stage of the operation has been completed.

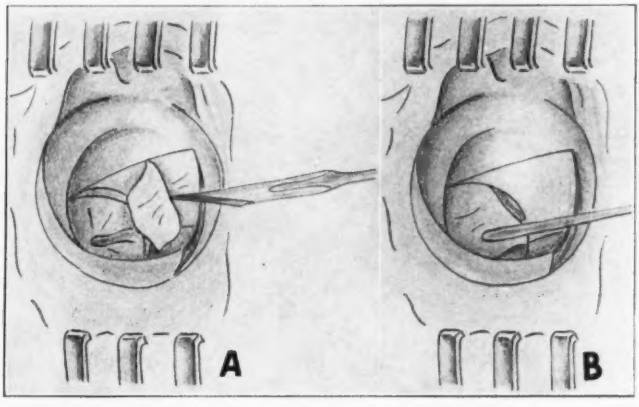

Fig. 6.—Stage 4. The tympanomeatal flap is reflected and safely stowed under the ledge of the tympanic plate. (The diagrammatic illustration of stage 4 is continued in figure 9.)

If careful and gentle manipulation is used, there will be no bleeding. It is important not to dissect anterior to the tympanic plate more than is absolutely necessary for its exposure, as in this region small veins may be encountered which may prove troublesome. Should this happen, a tiny strip of ribbon gauze soaked with a solution of epinephrine hydrochloride or with thrombin will control it instantly. It is advisable in that circumstance to anchor such a swab suitably; otherwise the swab is almost certain to be forgotten at the end of the operation.

The first stage of this operation is easy. With care and proper infiltration, it is bloodless. It is essential to clear the entire meatal cartilage both anteriorly down to the tympanic plate and superiorly to its attachment to the bony meatus.

STAGE 2.—*The Meatal Cartilage Is Detached and the Bony Meatus and the Tympanic Membrane Are Exposed* (fig. 2).—In this stage the meatal cartilage is carefully separated from its attachments, medially and superiorly. The cartilage is attached to the posterior edge of the tympanic plate. With a sharp-pointed

scalpel it is detached from below upward in a bevel-like manner. Note that the term "detached" is used, indicating that the cartilage is not incised. From the upper point of this detachment, the knife is swept outward to detach the meatal cartilage from the superior portion of the bony meatus.[4] Another point to be observed is that the knife must not cut the opposite side or the skin that is on the posterior portion of the auditory meatus. The tip must be allowed only to just perforate. The incision that detaches the cartilaginous tongue is therefore somewhat L shaped. The next maneuver in this stage is a major point in the final technic which makes the wide exposure of the next stage possible. The retractor is removed. A piece of gauze is inserted into the meatus and identified with a Killian speculum in the gap between the now free cartilage and the edge of the tympanic plate and bony meatus. The gauze is then drawn out from below upward through this gap, and the free edge is thus everted between the slings of this gauze and pulled outward and backward. The retractor is now reinserted in the following manner: The everted edge of the meatal

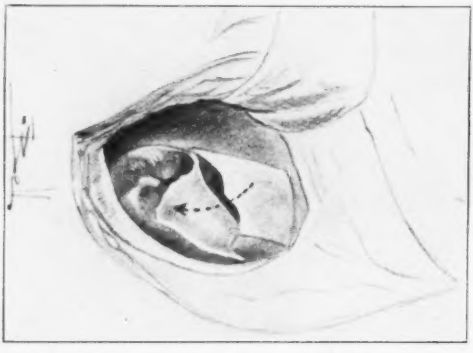

Fig. 7.—Realistic illustration of the reflection of the flap.

cartilage is engaged in the jaws of the retractor, and the latter is opened up. The tympanic membrane and the bony portion of the external auditory meatus are clearly and widely exposed.[4a]

4. An endaural incision of the skin down to bone of the bony meatus at 12 o'clock assists in accurate separation.

4a. An almost equally wide exposure can be achieved by an endaural incision running from 12 o'clock at the superior edge of the tympanic plate within the meatus outward to a point in front of the anterior convexity of the helix between the latter and the tragus, and a second incision across the superior bony meatus (fig. 3). The soft tissues are retracted. Possible objections are: (1) The circumferential integrity of the external auditory meatus is destroyed; (2) as the external auditory meatus is not widened at the expense of the mastoid process posteriorly in the transtympanic procedure, postoperative meatal stenosis would therefore be more serious than if mastoidectomy had been done; (3) alterations of shape in the cavity of the meatus may lead to disturbances of resonance within this cavity; (4) the antetragal incision is easier, gives better exposure and avoids the massive displacement of soft tissues necessary with the endaural incision.

The transtympanic approach was originally performed through an endaural incision, but the antetragal exposure described was considered to be superior. The cosmetic result is superb. The linear incision line is generally invisible at the end of the first week. However, many surgeons perform the transtympanic operation with an endaural incision and presumably consider that incision superior.

If, after retraction, it is found that the bony meatus is so narrow that only the posterior portion of the tympanic membrane is visible and the handle of the malleus is hidden by the projecting edge of the tympanic plate, the latter may be taken down. This is rarely necessary.

Method: The skin from the anterior surface of the tympanic plate is reflected backward, and with a small-bladed, goose-necked rongeur the protuberant portion

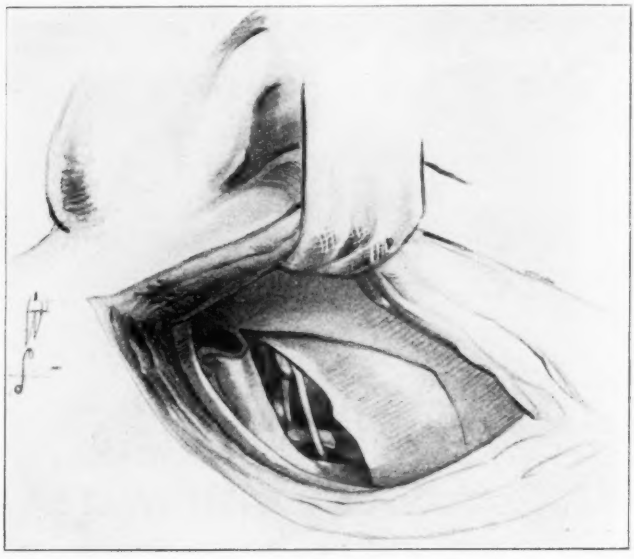

Fig. 8.—Realistic illustration of the exposure of the notch of Rivinus, the sulcus tympanicus and the tympanic contents (the long process of the incus, the chorda tympani, the stapedial tendon, the eminentia pyramidalis, the upper edge of the fossula of the round window).

of the tympanic plate is nibbled down. The skin is then applied to this surface. It will be found that little removal is necessary to expose the handle of the malleus to view.

Stage 3.—*The Tympanomeatal Flap Is Mapped Out* (figs. 4 and 5).—When the retractor has been spread, the next landmark is beautifully presented. It is the tympanic membrane, lying squarely at the bottom of the auditory meatus. The tympanomeatal flap must now be mapped out. If the purpose is to proceed from this operation to fenestration, then obviously the flap must hinge at the upper edge of the tympanic membrane as illustrated in figure 5.

If, however, an atticoantrostomy is being done, for which the transtympanic approach provides excellent exposure, the flap must hinge from the outer or opposite end and be detached from the sulcus tympanicus.

Mapping of the Flap for Fenestration: It is unnecessary to infiltrate the integument prior to making the incisions for the flap. Indeed, it is inadvisable to do so, as no bleeding is encountered. Infiltration tends to macerate and devitalize the thin skin encountered in this region. A plug of cotton wool soaked in epinephrine solution U. S. P. is gently packed into this region and left in situ for about one minute. The upper incision should not be too far away, always consistent of course with sufficient length to afford adequate cover for the eventual fenestra. This incision, therefore, is made to sweep across the auditory meatus from before backward to encircle approximately the upper half of the bony meatus. The incision is made down to bone with a sharp-pointed, small-bladed scalpel. The distance of this incision from the tympanic membrane is about 15 mm., or at the superior and outer edge of the tympanic

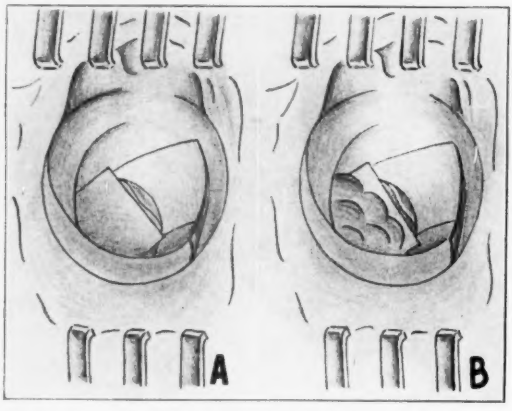

Fig. 9.—Stage 4 continued. To protect the flap from injury and fouling by bone dust, rubber tissue (*A*) and cotton wool pellets (*B*) are packed over it.

plate. After the cotton wool plug soaked with epinephrine solution U. S. P. has been removed, the next two incisions, which complete the flap, are made.

Anterior Incision: The handle of the malleus is identified and serves as a guide for the direction of this incision. The incision is made in line with the handle from the edge of the tympanic membrane at the sulcus tympanicus and runs outward to meet the upper or outer incision already described.

Posterior Incision: This runs parallel to the anterior incision and at a tangent to the posterior curve of the drum and outward to meet the outer or upper incision. Needless to say, both anterior and posterior incisions are down to bone. No doubt many surgeons practicing this technic have their own particular preferences and may modify this procedure according to their taste. The main point, however, is that in this region the skin is beautifully thin and pliable and requires no subsequent thinning down or other manipulation. It may be added that stages 1, 2 and 3 take longer to describe than to execute, but rigid attention to detail is imperative. The instrumentation is extremely simple,

and ordinary ophthalmic gear has been found most suitable. The ophthalmic forceps, curet and scissors and scoop are most useful. They are short, slender and delicate.

STAGE 4.—*The Tympanomeatal Flap Is Reflected and Stowed Safely Where It Is Protected from Injury and Fouling by Bone Dust* (figs. 6 to 8).—With a sharp-bladed knife, occasionally assisted by an ophthalmic curet and ophthalmic scissors, and dental pellets, the skin bounded by the incisions is now reflected from its bony bed. A sharp-bladed knife is used to evert the upper or outer edge. The blade of this knife is directed toward the bone. Owing to a suture in the temporal bone in this region, one often finds anchoring fibers firmly holding the skin down, and blunt dissection might result in tearing. By using an ophthalmic curet gently and occasionally small pellets of cotton wool soaked in epinephrine solution U. S. P., such fibers are easily exposed and snipped through with ophthalmic scissors. The skin is folded over as reflection proceeds right

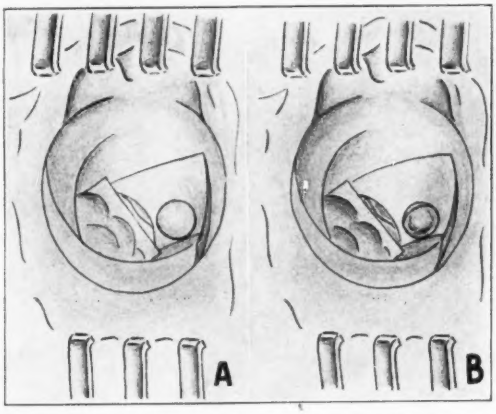

Fig. 10.—Stage 5. A perforation is made into the attic space. (The diagrammatic illustration of stage 5 is continued in figure 13.)

down to the sulcus tympanicus. At this point, an obturator membrane, the lining membrane of the middle ear, attaches the annulus tympanicus to the sulcus tympanicus. With a Lempert small-bladed separator this membrane is detached and the notch of Rivinus and the lower edge of the sulcus tympanicus exposed. Through this gap the chorda tympani will already have been seen, as well as the long process of the incus and the stapedial tendon, the eminentia pyramidalis and the upper edge of the fossula of the round window. The flap is now carefully folded over the upper part of the tympanic membrane with which it is continuous. It is now tucked underneath the ledge of the tympanic plate. To protect this flap further, a small piece of rubber tissue is placed over it, and, for good measure, on top of the rubber tissue small pellets of cotton wool are packed. These pellets are moistened and gently compressed, so as not to tear the underlying membrane, and the whole tympanic space below the sulcus is thus hidden. The flap is now safely stowed and forgotten until the very end of this operation. This fourth stage of the operation occupies but a few

minutes and presents no difficulties whatsoever. From now onward the entire procedure is supratympanic.

Stage 5.—*The Outer Attic Wall Is Removed* (figs. 10 to 13).—Professor Tato, of Buenos Aires, Argentina, performs this stage of the operation with very small chisels and a small mallet, swiftly and unerringly. My own preference is to use a diamond drill to perforate the outer attic wall at a point where the sulcus typmanicus and the edge of the anterior incision form an angle.

Instruments: The cable arm dental machine seems more efficient and flexible than the belt-driven type. A belt must be covered by sterile cloths; chafing and wear are excessive. The speed of the belt type machine is lower than that of the cable-driven type. Diamond burrs operate best at high speeds. The cut can be controlled to the minutest fraction of a millimeter at such speeds. Some workers assert that the vibration of the cable type machine disturbs them. Such vibrations do not occur in the better class equipment even when this is operat-

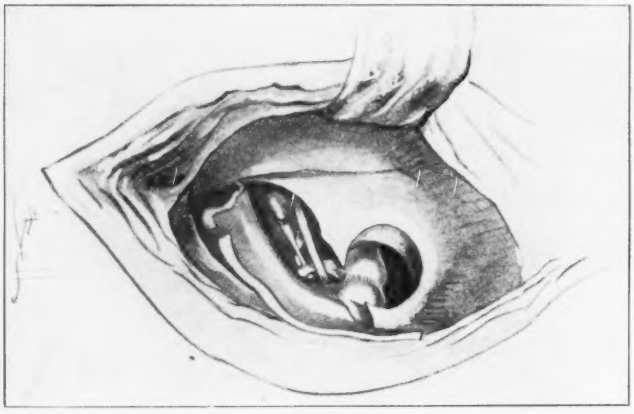

Fig. 11.—Realistic illustration of the perforation of the attic wall. This and figures 12 and 16 show the flap unprotected so as to emphasize its relationship. Note the crura of the stapes.

ing at the highest speeds. To be able to clean the cable arm with rectified spirit and then to enclose the whole length of it in a sterile sausage of linen gives one a feeling of comforting tranquility in the operating theater. An operating speed of over 3,000 revolutions per minute is desirable when one is using diamond burrs. It must be remembered that a cable arm has a spring wrist at its end and that this should not be flexed unduly. The engine, therefore, should be suspended in the direction of the head of the patient and at such distance and such height that the contra-angle hand piece, presently to be described, is always in line with the cable arm of the engine. Should the wrist spring be damaged during the operation, it can be replaced by a spare wrist which, of course, is always available in a matter of seconds. The standard dental contra-angle hand piece is certain to win approval. Surgeons accustomed to this advanced form of operative work will find that the short contra-angle hand piece affords much better visual control. The contra-angle hand piece

should be of the slip-on joint type, and the corresponding fitting on the cable arm of the dental machine must be selected. This is standard equipment which can be supplied from the stock of any dental depot. Standard long dental diamond burrs are used. Long burrs are not designed to be used with the contra-angle hand piece; the ends of these burr shafts have to be specially flattened and grooved to fit the instrument. Any dental mechanic is able to do this in a few minutes. The length of these burrs must be sufficient to reach the field. A sleeve or bushing to prevent "whip" is also special equipment. It is best to assume that the instrumentation of this work is not common knowledge and to describe what is used in detail. No apology is needed, therefore, for this lengthy digression. Only four types of diamond burrs are used—a cylinder, a sphere, a disk and a cone. The diamond burr may be described as a perfect surgical instrument. Its cut can be controlled within the smallest fraction of a millimeter; it never wears out; no pressure is needed—in fact, is undesirable; it fragments the endosteum so that portions of the endosteal membrane come away

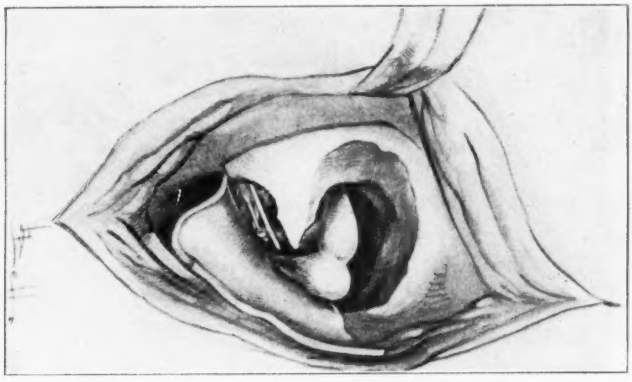

Fig. 12.—Realistic illustration of the removal of the attic wall.

with such fragments and the fistula requires a minimal amount of intervention to remove endosteal membrane.[5]

With the diamond cylinder placed in the angle formed between the sulcus tympanicus and the anterior incision of the flap, the next step is to drill an opening into the attic. The end of the diamond burr is placed at this location. The foot switch operating the dental machine is depressed and a socket formed in the outer attic wall. The foot switch is released, the field is flooded and irrigated with a penicillin solution, and aspiration is carried on until every vestige of bone dust is removed. Under no circumstances whatsoever may a rotating burr be introduced or removed from the field while it is in motion, and the

5. The diamond burrs referred to are made for me by the B. L. Dental Corporation, Long Island, N. Y. (cylinder nos. 225 and 232, sphere nos. 223 and 226, disk no. 236, and cone no. 229). I am in touch with this firm to supply this equipment already modified to fit contra-angle hand pieces, and these diamond burrs should be available by the time this paper is published. The shafts are 2¼ inches (about 6 cm.) long.

surgeon should practice until this sequence of placing the burr, depressing the switch, releasing the switch, and removing the stationary burr becomes a reflex. This reflex is swiftly acquired and will banish mental strain. The diamond cylinder is replaced in the socket it has created and allowed to rotate at maximum speed for ten seconds without any but the gentlest pressure being used. Again the field is cleansed after withdrawal of the burr, and this process is repeated until the attic is perforated. The surgeon feels a slight "give" as the tip of the diamond cylinder sinks into the attic space, and, as only the slightest pressure has been used, there is not the remotest danger of any injury being done to the attic structures. After the field has been thoroughly cleansed, the body of the incus will be visible through the perforation.

The smallest size Lempert curet (0000) is now introduced into this opening, and, with the scoop facing the surgeon, the bony bridge between this opening

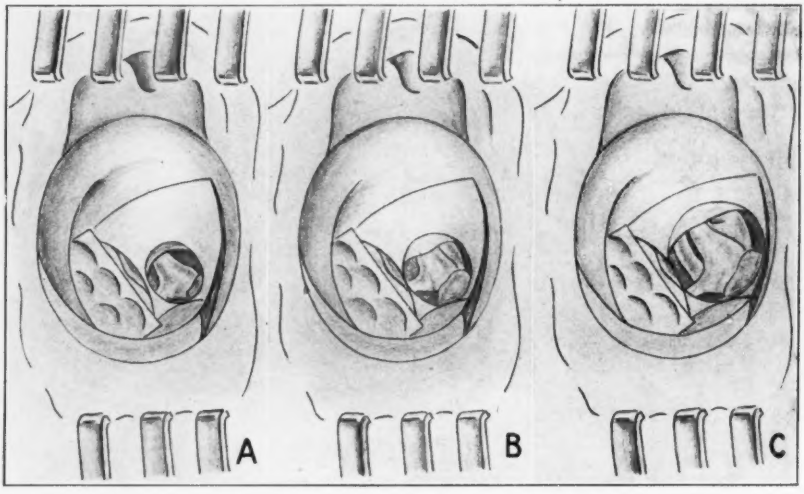

Fig. 13.—Stage 5 continued. In *A*, after perforation of the attic wall, the body of the incus is exposed and the incudomalleolar articulation becomes visible. In *B* the opening is enlarged, and the upper part of the fenestration site is visible. In *C* the entire incus is exposed, with the facial nerve appearing below the short process of the incus.

and the free lower edge of the attic wall is fractured outward. The curet is reinserted, and this procedure is repeated until the entire incus is exposed, the bone being fractured outward in every case. Not only will the entire incus now be visible, but also its articulation with the head of the malleus. After gross removal of bone with the Lempert curet, the disk diamond burr is used to open the attic as widely as possible right up to the tegmen and backward to the aditus ad antrum, so that this entire region is completely exposed to view. Previous difficulties and stenoses were due to failure to adopt this wide exposure. With the diamond disk burr it is possible to use three surfaces, the flat end, the rim and the upper surface. The edge of this burr is hooked under any projection which is to be cleared; one gently pulls the instrument outward, using the upper

diamond surface and working away from the tympanic structures. The burr is removed approximately every ten seconds to minimize the generation of heat, and the field is cleansed as has already been described. With the incus still in position, the ampullated end of the lateral canal or "dome" can be seen in the upper region of the field above it, the facial nerve below the short process, and the chorda tympani crossing its long process.

In otosclerosis the incus has no function, and in fenestration its removal is necessary for exposure of the fenestration site.

Prevention of Permanent Deafness Following Removal of the Incus in Mastoidectomy.—Almost every otologist must have made the observa-

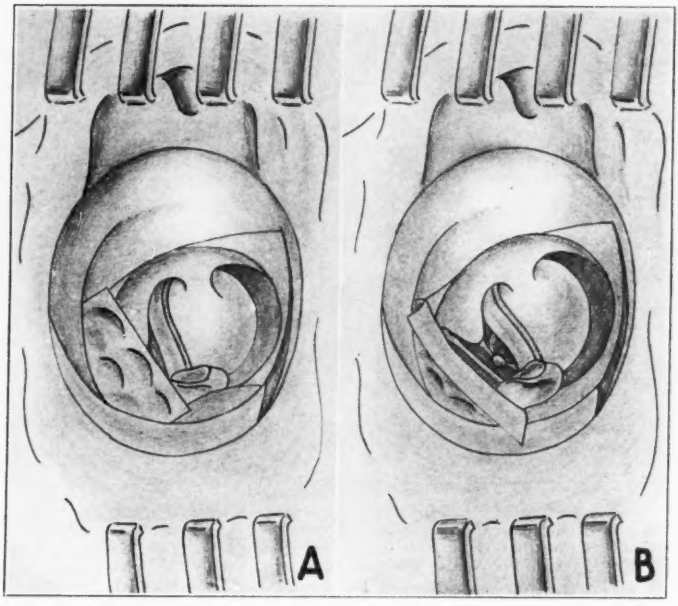

Fig. 14.—Stage 6. In *A* the incus has been removed, the attic is open up to the tegmen, the ampullar dome is clear and accessible, and the facial nerve with the blood vessel at its upper border. *B* shows the field prepared for a test for fixation of the stapes. The head of the malleus does not obstruct the view of the site of fenestration.

tion that after the incus has been removed during radical mastoidectomy the hearing that was present on the affected side is gone. In an address at the Annual Session of the American Medical Association in Chicago, on June 23, 1948, I put forward an explanation of the functions of this ossicle and urged that when the surgeon is doing atticoantrostomy for chronic otorrhea he in no circumstances disturb

the incus if the object of the operation is to restore hearing as well as to control the discharge. With the gentle technic of the transtympanic approach, the incus can be saved. In radical mastoidectomy, however, whether postaural or endaural, damage of the incus is difficult to avoid and the ossicle is frequently sacrificed, with corresponding inevitable loss of hearing. The loss is in the region of 40 decibels.

Such a loss will occur when the incus is removed, and on examination its lenticular process is found to be undamaged by disease.

The deafness is due to the tonic contraction of the stapedius muscle, which now, being unopposed, pulls the stapedial footplate out of the

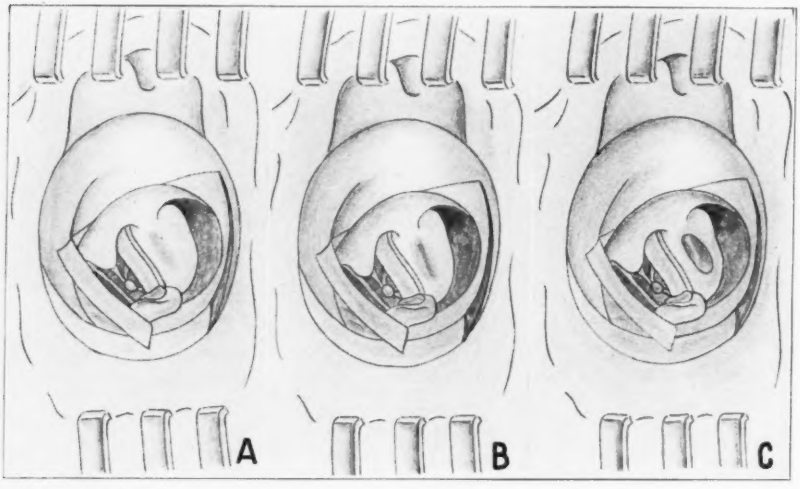

Fig. 15.—Stage 7: fenestration. In *A* the superior, anterior and lateral surfaces of the dome are being ground down. A gray line shows. In *B* the capsule is thinned further. The gray line darkens. In *C* the fenestration has been completed. The site is vertically over the stapes. The membranous canal is visible.

oval window. Excursions of the perilymph are dampened. As no opposing mechanism now exists to poise the footplate correctly, such dampening with consequent deafness will be permanent if stapedial muscular control is allowed to persist. This control must be banished. It is essential to divide the stapedial tendon between the eminentia pyramidalis and its insertion into the neck of the capitulum of the stapes. The stapes is now free, and hearing has been preserved by the labor of a few seconds.

It has been shown experimentally that stapedial excursions are two and even three times greater after the tendon is cut.

The ear is, of course, deprived of the mechanism that protects the cochlea against acoustic injury (excessive noise).

If disease has involved the lenticular process, together with the capitulum of the stapes and its tendon, tonic action affecting the footplate does not arise. This may account for the remarkably good hearing frequently encountered in the presence of chronic middle ear disease with obvious osteitis and cholesteatoma.

Fig. 16.—Realistic illustration of the exposed attic. Cortex still covers the antral region; it is removed as well in the current technic. Note the dome, the fenestra and the membranous canal, the facial nerve, the chorda tympani, the stapes, the stapedial tendon and eminentia pyramidalis, the round window, the tympanomeatal flap and the head of the malleus. The flap is about to cover the fenestra.

With the end of stage 5, therefore—that is to say, with the incus still in position—the atticoantrostomy by the transtympanic approach has been completed. The attic and the antrum are carefully searched for any diseased material, which is removed either with Lempert curets or diamond burrs until a healthy base is seen. The meatal flap, in this instance hinged from its outer edge, is now replaced against the cleaned out attic and adapted to its new base by gentle packing. Viscose sponge material is used for this purpose. These small sponges are dipped in liquid petrolatum U. S. P. and covered with sulfadiazine powder,

and are used in the form of a rosary as shown later for the fenestration procedure.

STAGE 6.—*The Incus Is Removed* (fig. 14).—The attachment of the incus is loose, and even the gentlest manipulation dislodges it from its bed. With a pair of fine forceps (ophthalmic) the long process is grasped and the whole ossicle gently lifted upward so as to avoid tearing the chorda tympani. The attico-tympanic structures are now in view.

With removal of the incus the time has come to check the diagnosis of otosclerosis, or, in other words, to establish whether the stapes is fixed. After removing the cotton wool pellets which have packed off the tympanomeatal flap, it is possible to turn over the upper edge of the drum and inspect the entire stapes. The capitulum is now free, and I have found that in fixation it invariably is permanently tilted in a downward direction. I should be interested to know

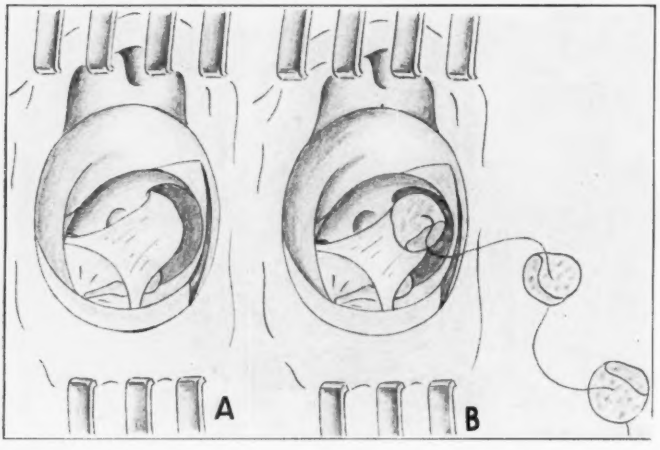

Fig. 17.—Stage 8. In *A* the tympanomeatal flap is replaced. In *B* a rosary-like sponge pack dusted with sulfadiazine is being applied.

whether this downward dipping is a constant characteristic in fixation, and colleagues' observations on this point will be welcomed. With a fine needle the capitulum is touched lightly, and it is almost invariably found that the fixation is absolute. The crura of the stapes are so delicate that if the slightest force is used they will fracture. It must be remembered that the diagnosis of otosclerosis is based entirely on presumptive evidence, and it is always a relief when this test is over. Should the stapes be freely mobile (and here one must make quite sure that the footplate is rocking with the capitulum and that the crura have not been fractured), it is purposeless to proceed to fenestration of the vestibular "dome." Lempert has described otosclerotic foci occurring in the round window region, and this would produce exactly the same symptoms as fixation of the stapes. In such an event, fenestration of the scala tympani is indicated. Such procedures are still in their experimental stage. After the test for stapedial fixation has been completed, the cotton wool pellets are again packed into the space below the

ledge of the tympanic plate to protect the tympanomeatal flap, and the stage is set for the actual fenestration procedure.

STAGE 7.—*Fenestration Is Performed* (figs. 15 and 16).—Extra magnification with loupe or microscope is used in this stage. I follow the teachings of Lempert

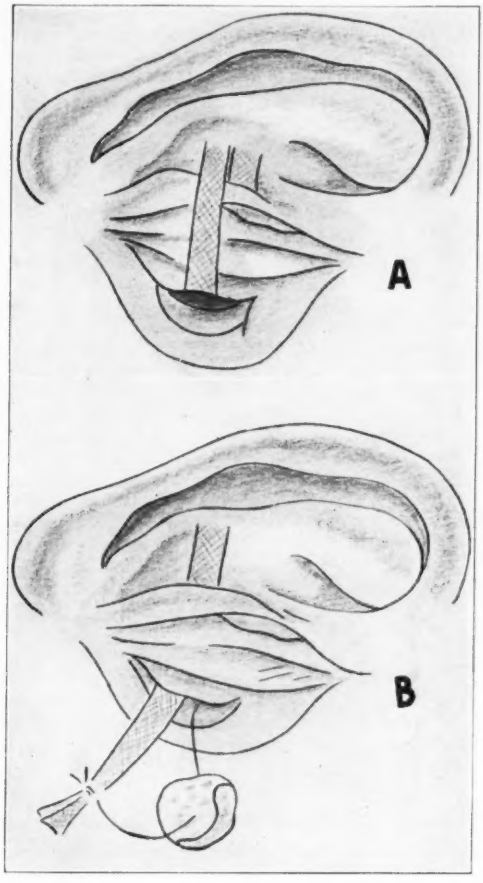

Fig. 18.—*A* shows the retractor released and the linen thread of the rosary pack attached to gauge in the meatus. In *B* the linen thread is drawn into the meatus.

closely and intend to use the lead burrs which he recommends when these are available. The fluid state of thought on this subject is exemplified by the diversity of views expressed in different schools. Any of the existing technics, including

that of uncapping, can be used in the transtympanic exposure with comfort and safety, and the ideal site vertically above the stapes is there for the asking. In fig. 15*A* the ampullated "dome" is shown ground down superiorly, anteriorly and laterally, with the gray line of the eventual fenestration showing through. A further stage is shown in figure 15*B*, with the gray line showing through much darker. For this preliminary grinding down, the spherical diamond burr is most useful. At this point it may be changed for the flat end, inverted cone

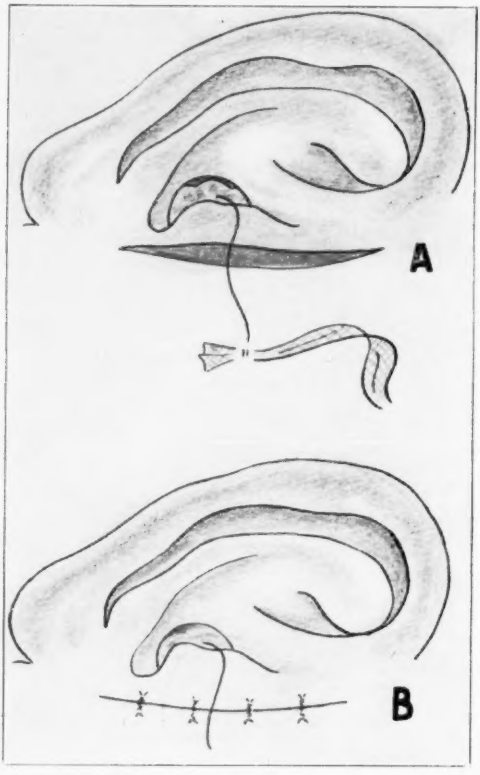

Fig. 19.—In *A* the meatus is lightly packed with a strip of the sponge material. In *B* the edges of the incision have been sutured.

diamond burr, which is played over this darkened gray line until fragments of endosteum, usually with some endosteal membrane attached, come away. During this maneuver, either continuous irrigation and suction or cleansing of the field every few seconds may be employed. Great care must be taken that the suction tube is placed nowhere near the fistula. All bone dust and fragments of endosteum and endosteal membrane are flooded away from the site of the fistula,

aspirated or mopped and the region carefully inspected after each irrigation to make certain that no vestige of debris remains behind. Tiny pellets of cotton wool soaked with penicillin solution are used to mop the surface of the fistula until eventually it has reached its maximal size and a few shreds of endosteum may be seen clinging to its sharp-edged rim. With a fine needle and with the field flooded with penicillin solution, these shreds are gently teased away without the needle entering the interior of the fistula. The field is mopped dry and the fistula inspected. When the shining endosteal membrane lining the cavity and the membranous canal can be clearly seen in the fistula as shown in figure 15*C*, one or other of the polishing burrs, lead or gold, may be used over the rim surrounding the site of fenestration.[6]

Stage 8.—*The Tympanomeatal Flap Is Replaced* (fig. 17).—The protective cotton wool pellets and the rubber tissue are now removed from the osteal surface of the meatal flap overlying the tympanic membrane. The field is again flooded with penicillin solution, and the flap is gently teased away from its anchorage under the tympanic plate until it floats. In no circumstances must suction now be used, or one may find the flap in the suction bottle. The flap has a natural tendency to fall back to its original position. On gently mopping away the excess fluid, the flap can be made to sink down and cover the site of the fenestration like a ship gradually touching bottom in a dry dock. Before allowing the flap to settle, it is as well to inspect the fenestration again and make quite sure that no bleeding into the lumen has occurred. When this point has been satisfactorily settled, the flap is allowed to fall into position. Again with the use of minute cotton wool pellets, this time soaked in liquid petrolatum U. S. P., so that the flap may not adhere, the flap is adapted to its new position and the skin pushed closely into the fistula. Viscose sponges threaded on linen in the form of a rosary and soaked in liquid petrolatum U. S. P. and dusted with sulfadiazine are convenient. These are packed gently over the flap until the attic is full. The interstices between the sponges allow ample drainage. The end of the linen thread is pulled from below through the meatus, care being taken not to dislodge any of the sponges in the attic. The meatus is lightly packed with a strip of the same sponge material, and the edges of the incision are allowed to fall together. Two or three sutures generally suffice or, preferably, Michel clips may be used. These are removed on the fourth day. There is no tension in this region, and the cosmetic result is perfect, the scar being barely visible even after one week. The meatal sponge is removed on the fourth day. Penicillin in oil is instilled three or four times daily. The patient usually is able to walk unassisted on the third day. The attic and flap sponges are removed piecemeal from the seventh to the tenth day. A forty-eight hour course of penicillin therapy is administered as a routine after operation.

COMMENT

A celebrated portrait artist once asked me to inspect a painting—my wife was the subject. When I reached his studio, I found the

6. Recently I had the opportunity of investigating the work of Dr. Samuel Rosen, of New York. Rosen developed the technic of implanting the chorda tympani in the fistula as a pedicle graft. The nerve is detached as it emerges from the facial canal and inserted in the fistula either as a single trunk or as one doubled on itself. The transtympanic approach affords an excellent exposure for this maneuver. The promising results of Rosen's technic will be capable of final evaluation in due course.

model still posing and was told to return the following day. To me the portrait seemed complete, and I was puzzled when, on the following day, I noticed no difference whatsoever. The artist explained this to me and confessed that he did add something but decided to remove the addition. I then asked him by what standards or what criteria he judged a work of art to be completed. I shall never forget his reply. He said, "A work of art is completed when it complies with three rules. Firstly, when the effect that the artist set out to produce has been achieved; secondly, if anything omitted would detract from this effect; and, thirdly, when anything added will not enhance the effect." It is my hope that with the help of my colleagues the transtympanic approach will stand up to this test.

The line drawings were made by Miss Ann West, B.A., from her own dissections. The other illustrations were presented to me by Dr. Bello, of Buenos Aires, Argentina.

Prof. Sutherland Strachan, of the department of pathology of the University of Witwatersrand Medical School, and his staff, with Prof. W. E. Underwood, of the department of surgery, gave assistance and advice.

Fifth Floor, Lister Building.

ABSTRACT OF DISCUSSION

Dr. Douglas G. Carruthers, Sydney, Australia: Since Dr. Popper published the description of his method in the *Journal of Laryngology & Otology* in January 1946, I have performed that procedure many times on cadavers and a number of times on living subjects. I am in a position to consider the procedure which has been expounded to you today as a result of actual experience. Whichever of the incisions one may employ, I find that the field of access is not adequate without partial removal of the tympanic plate. Subperiosteal isolation of the tympanic plate is readily achieved, without risk of injury either to the facial nerve or to the temporomandibular joint and with but little hemorrhage. After one has gained access to the external auditory canal, the beautiful exhibition of the tympanic membrane and landmarks certainly is most impressive and satisfying. This is the only aural operation I know in which such a direct view of the drumhead is obtained. For that reason alone, it must find a useful place as a practicable approach to intratympanic and cochleovestibular surgical intervention.

The next procedure is to outline the flap of integument and to elevate it off the posterosuperior wall of the external auditory canal. This area presents itself "square on" to the operator. The flap can quite readily be stripped off the bone right down to the tympanic annulus, where, as a result of the clear view and direct access which have been provided, separation of the posterosuperior margin of the tympanic membrane, continuous with the base of the flap, can be performed so readily as to be surprising. The tympanic cavity is thus speedily and safely opened. Now the long process of the incus presents itself as an unmistakable landmark defining the exact site for the subsequent removal of overlying bone and clearly indicating the depth to which one has to cut away bone.

The only drawback of the whole operation, yet one which experience soon teaches one to master, is that when the stage is reached at which one has to use the engine-driven burrs, the field is found to be somewhat restricted. A contra-angled hand piece leaves a little more room. I am sure that a hand piece of more slender shaft can be designed so as to leave much more room for observation of the center of the field. Until the attic has been opened there is not much opportunity to use the burrs for side reaming. I would stress that there is no need to fear the procedure on account of this relatively small field which the

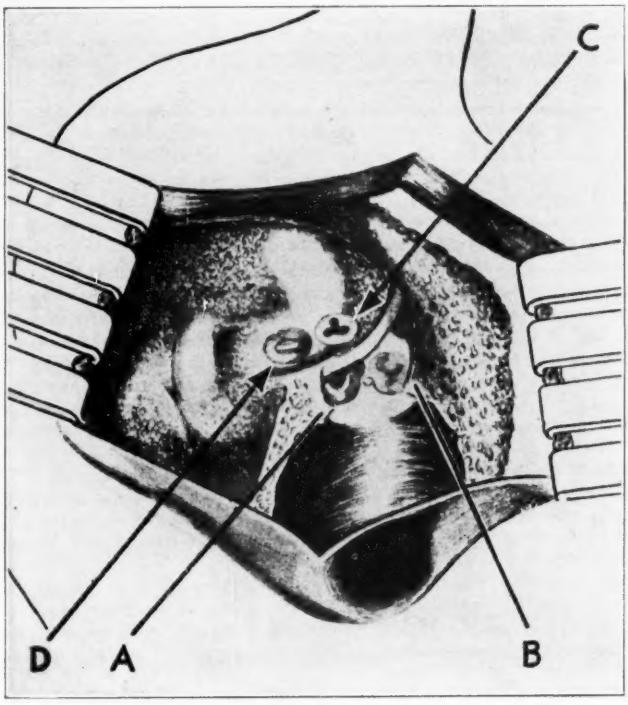

Fig. 1.—Fenestration by the transtympanic approach of Popper: *A*, posterior buttress of the annulus tympanicus; *B*, anterior buttress of the annulus tympanicus. Both *A* and *B* require to be taken down to insure a good "lie" of flap. *C* indicates a triradiate fistula made in fenestration of the dome; *D*, an oval fistula on the ampulla of the lateral canal. The ideal site is between *C* and *D*.

surgeon has to work in. A little practice on the cadaver soon gives the necessary confidence, and one learns how to adjust the lighting and the magnifying system so as to see what is being done. The body of the incus lies beneath the bone which is being removed, and if the operator should be a little heavy handed, it serves as a protection to deeper structures as the attic is entered. When in due course the incus is removed, the anterior-most portion of the external semicircular canal and adjacent wall of the vestibule are presented in relief right in the center of the field. There is no doubt whatsoever about where to make the fenestra so

that it will be as close as possible to the natural oval window. I have always had some doubts about the accessibility of the true vestibule when using the endaural approach. I have always felt that what was described as fenestration of the dome of the vestibule was fenestration of the ampullary end of the external semicircular canal. I don't deny that the vestibule can be entered by the endaural route, but I feel that at the angle of approach from above and behind which is so provided, only a minute segment of the vestibular wall is accessible. When employing the transtympanic route of Dr. Popper one finds that the angle of approach is a full 90 degrees farther forward, and I do believe, as a result of careful studies of the highly magnified field of the cadaver, that it is practicable in many cases to expose the vestibular space anterior to the ampulla of the external canal with reasonable certainty. Whether there is any real advantage in placing a fenestra so far forward is, of course, as yet unproved.

The flap of integument used to cover the fenestra is extremely thin, and being cut deep to all cartilage, it is flexible and can be readily adapted to the site of fenestration. I have been troubled much with excessive granulations in the depth of the canal, and later stenosis has been too frequent after this method has been used. I believe that the tendency toward these unsatisfactory sequelae points to the necessity to make the bony atticomastoidectomy much more extensive and indicates also that the tympanomeatal flap should be much larger. Both of these modifications of procedure are quite practicable via Popper's approach.

I present to you in brief outline the histories and the audiograms of 4 of my patients who have been operated on by Dr. Popper's method. They serve to support the claim that an improvement in hearing comparable with that of any other method can be achieved by the transtympanic approach. I am attracted to the method because of its simplicity and because the access obtained is so much more direct than that by any other approach. I would stipulate, however, that much as one may have operated by other methods, an attempt at a new approach is not always easy. Just as otologists have had to prepare themselves for the endaural method by assiduous and often repeated practice on cadavers, so they must do this again before it is reasonable that they will correctly assess the new method. The surgeon who would just try the transtympanic approach once or twice, and be turned back by its little difficulties rather than master them, will, I am sure, deprive himself of much of the pleasure which comes of being able to orientate oneself to a new surgical environment. I still operate by both Lempert's and Popper's approach and I have many technical points which are my own. I am not prepared to say yet that any one method is entirely better than the other.

The major significance of Dr. Popper's work as I see it is that he has devised a simple and practicable anterior transmeatal approach to the posterior portion of the tympanic aditus and vestibuloampullary area. As such it will be, I am sure, of lasting use in the practice of otologic surgery.

Dr. Arthur L. Juers, Chicago: I commend Dr. Popper for his diligent efforts to improve the surgical approach to the middle ear region and the position of the fenestra. However, as far as fenestration is concerned, I cannot, at present, conceive of sufficient advantage of the transmeatal approach over the Lempert endaural technic to warrant using the transmeatal route. Several months ago Dr. Shambaugh modified the regular endaural technic by cutting the flap and freeing it almost down to the tympanic ring before opening the mastoid cortex. I have since adopted this change and I find that it facilitates the early part of the operation. This modified endaural approach, in addition to utilizing the meatus as part of the avenue of approach to the labyrinth, affords the surgeon an oppor-

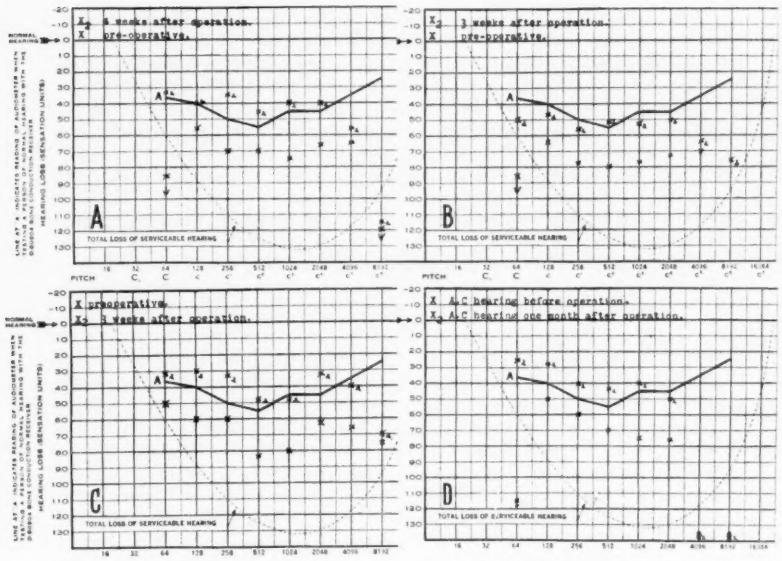

Fig. 2.—Audiograms of patients on whom fenestration was performed by the method of Popper: *A*, audiogram of N. J., aged 13. Deafness had been progressively increasing since the age of 9 years. The father was deaf, his loss of hearing having started when he was 10. Several aunts were deaf. No deafness was found on the mother's side. The patient had no other ear troubles. The nose and the throat were healthy. The ears appeared normal. The eustachian tubes were patent. The Rinne test showed hearing by bone conduction much stronger than that by air conduction. An audiogram revealed nearly normal bone conduction in both ears except for a loss of perception of 8192 cycles. Fenestration of the left labyrinth was performed by Popper's technic on April 5, 1948. Healing was uneventful. There was marked improvement in the patient's hearing of normal conversation. The postoperative audiogram confirms the improvement in hearing. The average gain throughout the speech range was 30 decibels.

B, audiogram of Mrs. W. R., aged 31. She had noted deafness, especially of the left ear, for about five years. The father was deaf. A grandmother and one cousin were deaf. The patient has no other ear troubles. The ears appeared healthy. The eustachian tubes were patent. The Rinne test showed hearing by bone conduction stronger than that by air conduction in both ears. In the Weber test the sound was central. A bone conduction audiogram, with masking, indicated fair but uniformly reduced cochlear activity in both ears. An air conduction audiogram indicated that the hearing of the left ear was 10 to 15 decibels poorer than that of the right. On Oct. 27, 1947 fenestration was performed on the left labyrinth by Popper's method. The membranous labyrinth was intact and there was an intact flap. Rather exuberant granulations were observed in deep portions of the external auditory canal during convalescence, but were completely healed on Dec. 12, 1947. The audiogram reveals 25 to 30 decibels gained in the speech hearing range. The gain has been maintained.

C, audiogram of Mr. G. W. aged 35. His deafness was of gradual onset, especially during the past five years, and was worse in the left ear. There had been no previous ear troubles. No relatives were deaf. The drumheads revealed slight opacity only. The eustachian tubes were patent. The Rinne test showed

(Legend continued on next page)

tunity to remove as much additional bone as is necessary to provide adequate exposure of the lateral semicircular canal. An attempt to carry out fenestration by the transmeatal approach described by Dr. Popper without removing the entire lateral wall of the mastoid antrum would make an already difficult surgical procedure more difficult. The mastoid antrum must be opened widely if an adequate removal of periosteal bone from the lateral semicircular canal is to be accomplished (enchondralization). Furthermore, if all the bone lateral to the antrum is not removed, then there exists after operation a recess or pocket which would undoubtedly, in some instances, be invaded by squamous epithelium from the distal end of the flap, and a cholesteatomatous mass might be formed eventually. If by the endaural technic the operative cavity is kept as small as is compatible with providing adequate exposure of the lateral semicircular canal, and if strict asepsis is observed in the early postoperative treatment as well as during the surgical procedures the after-care of the cavity will be relatively simple.

The size of the flap described by Dr. Popper would be inadequate to seal off completely the middle ear in the anterior area of the attic. I believe that this failure to seal off the middle ear would in some instances result in a permanent perforation of the attic with subsequent poor improvement of hearing.

Dr. Popper has stated that he prefers to place the fenestra anterior to the position of the fenestra nov-ovalis. After doing some detailed dissections of the lateral semicircular canal and the lateral wall of the vestibule, I find that I cannot agree that it is desirable to attempt to place a fenestra anterior to the present nov-ovalis position. There are, in my opinion, three reasons why this more anterior position is not desirable.

1. At the point where the membranous canal joins the ampulla, the perilymphatic space begins to turn inferiorly and medially. In this region the course of the facial nerve is in an anterior and superior direction, and any attempt to place the fenestra on the anterior surface of the ampulla would place it unnecessarily close to the facial nerve.

2. If an attempt is made to place the fenestra on the anterior aspect of the ampulla, the branches of the vestibular nerve supplying the ampullae of the lateral and superior canals might be severed. This is obviously undesirable.

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hearing much stronger by bone conduction than by air conduction. In the Weber test the sound was central. An audiogram revealed good hearing by bone conduction in both ears. The tonsils were suspected and removed, and the antrums were washed out and treated with penicillin as a precautionary measure prior to fenestration. On Feb. 9, 1948 fenestration of the left labyrinth was performed by Popper's approach. The membranous labyrinth was intact, and the flap was intact. On February 27 the fistula response was active; the flap and the fenestration area were healed. There were granulations tending to project into the deep portion of the meatus. Hearing was greatly improved. The audiogram reveals a gain of over 30 decibels in the speech range.

D, audiogram of Mrs. W. H., aged 42. Deafness, worse in the left ear, started after pregnancy when the patient was 30. There were no other ear troubles. No relatives were deaf. The nose and the throat were healthy. The ears appeared normal. The eustachian tubes were patent. The Rinne test showed hearing by bone conduction much stronger than that by air conduction. An audiogram revealed hearing by bone conduction to be almost normal except for a sharp drop at 4096 and 8192 cycles. Fenestration was performed on the left labyrinth on Jan. 22, 1948. Healing was uneventful. Postoperative audiograms taken on February 18 indicated a gain of about 25 decibels throughout the speech range. As anticipated, there was no lift at the high end of the auditory spectrum. In May, four months after operation, the hearing gain was still well maintained.

3. If the entire fenestra is placed directly over the ampulla, it is quite possible that the patient will be subject to more unsteadiness on quick movement in years to come than he would be if the fenestra were placed somewhat more posteriorly, with less exposure of the ampulla.

From a physiologic standpoint I believe that the best position of the fenestra may be on the most lateral aspect of the canal, because this provides maximum phase difference for a sound wave at the fenestra and the round window.

My colleagues and I will await with anticipation more extensive and more conclusive long range clinical reports as to results obtained by Dr. Popper's fenestration technic.

Dr. Scott Stevenson, London, England: I had no intention of taking part in this discussion this afternoon, but I could not resist the opportunity of congratulating my old friend, Dr. Popper, on the ingenuity of his operation. In our hospital, where we have done a certain number of operations of this type, we have been inclined to teach our students that the difficulty is in the flap rather than in the fenestra, and I do think that Dr. Popper's operation seems to make the handling of the flap easier. It has been pleasant to be here, because some twenty years ago he and I worked together as juniors in University College Hospital in London, and it was a great loss to England when Dr. Popper made up his mind to go back to South Africa.

I take the opportunity of conveying greetings to you from the British Medical Association and also from the Royal Society of Medicine. We will have an international congress in London in July 1949, under the presidency of Mr. Victor Negus, our leading laryngologist. I have been asked to give the most cordial invitation to all the members of the Section on Laryngology, Otology and Rhinology of the American Medical Association to come to the international congress next year. You will find that conditions in England are not as bad as they were—not as opulent as they are over here, of course. If you live in hotels you will not find anything much wrong at all; our Ministry of Food turns a somewhat blind eye toward hotels and restaurants, and we encourage visitors, of course. We can certainly promise any otolaryngologist who comes over next year a good time.

Dr. Otto Popper, Johannesburg, South Africa: Dr. Juers stated that he sees no advantage in doing my operation, over the accepted method. The advantage is that you omit the preliminary radical mastoidectomy. Naturally, it is a question of how great you consider this advantage. There are some who consider it very great, more particularly surgeons in Scandinavia, Holland, France, Argentina and elsewhere who have done many hundreds of operations according to my method. I have just had a letter from Professor Lund, of Copenhagen, who is publishing his first series.

May I say, let us leave the comparison until a time five or six years hence, when it can be adequately determined whether my method should be thrown onto the scrap heap or whether it will endure? Nothing I can say will help. It is only the intrinsic merit of the operation that will allow it to survive.

I am particularly honored that such an international celebrity as Dr. Carruthers should fly 10,000 miles to support me, and I am grateful for the courageous way in which he has expressed himself. Douglas Carruthers' classic on rubella and deaf-mutism is medical history and has placed him in the front rank of famous otologists. To have won the approval of such a careful and painstaking investigator is a great encouragement.

I am grateful to my old friend Scott Stevenson for his kindly thought; we starved together in those heppay London days and I rejoice and would like it to go on record that he approves—even if it has taken him two decades to do so.

I thank you, gentlemen, very much.

ACOUSTIC, VESTIBULAR AND OTHER PROBLEMS CONCERNING OTOSCLEROSIS AND ITS SURGICAL TREATMENT ACCORDING TO POPPER'S METHOD

ROBERT LUND, M.D.; HARALD EWERTSEN, M.D.; HELMER RASMUSSEN, M.D.; NIELS RISKAER, M.D., and SVEND SELSØ
COPENHAGEN, DENMARK

I. POPPER'S OPERATION FOR OTOSCLEROSIS

ROBERT LUND, M.D.

IN JANUARY 1946 Popper[1] brought out his "new, safer and less traumatic approach to the labyrinth—the transtympanic route." His technic offered such a striking simplification of the operation for otosclerosis as compared with previous methods that I decided to try it.

In the course of years, as is well known, the site of the labyrinthine fenestration has gradually shifted more and more forward from the lateral limb of the ampulla of the lateral semicircular canal to the ampulla itself and finally to the very roof of the vestibule, above the facial canal. In the employment of the Lempert operation, however, the transmastoidal route has been preserved. In this way the lateral semicircular canal is placed anteriorly in the operating field, it is true, but this technic is less suitable when it is desirable to place the fistula in the cupola of the vestibule corresponding to the lateral ampulla and the area in front of this, because this portion of the labyrinth is not directly accessible.

These features are illustrated well in figure 1, a drawing taken from Popper's article.[1]

In figure 1 the line *1—1* is the axis of the labyrinth as related to the cranium. The arrow *L* shows the direction of the approach in Lempert's transmastoidal method, i. e., an oblique approach, which naturally makes the chiseling technic more difficult. The arrow *P* gives the direction of the approach—thus, also the drilling direction of the burr—in Popper's method; i. e., the approach is "square on" the operating field, perpendicularly on the vestibule, where the fenestra is to be drilled; and this naturally means a much easier approach. *T* indicates that part of the labyrinth which is covered by the anterior tympanic

From the Ear Department, Sundby Hospital, Copenhagen (Chief: Prof. Robert Lund, M.D.).

1. Popper, O. F.: J. Laryng. & Otol. **61**:24 (Jan.) 1946.

plate, i. e., the cupola of the vestibule. *M* indicates that part of the labyrinth which is covered by the mastoid process and its pneumatic cells, i. e., the area of the semicircular canal. In other words, if one is to operate on the vestibule, or merely on the lateral ampulla, a really "square-on" working field may be obtained only by going through the anterior wall of the meatus.

Now I shall describe briefly the Popper technic, with those modifications which I have found advantageous.

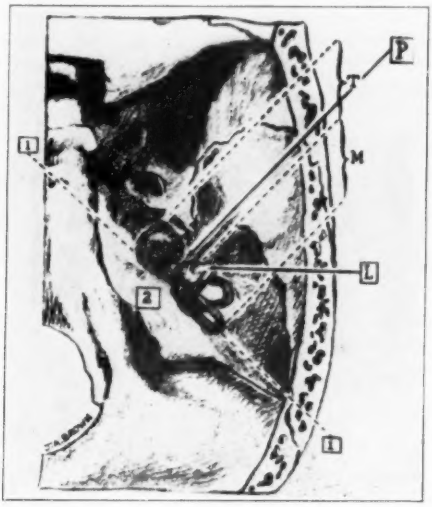

Fig. 1 (after Popper[1]).—*1—1*, the axis of the labyrinth, shows that this structure is inclined at an angle of 45 degrees to the sagittal plane. *M* includes the part of the labyrinth covered by the mastoid process. *T* includes the part of the labyrinth covered by the tympanic plate. *P*, an arrow, shows the direction of the transtympanic approach and the "square-on" presentation of vestibule. *L*, an arrow, shows the direction and the oblique presentation of the operative field in the transmastoidal approach. *2* is opposite the vestibular region of the labyrinth.

TECHNIC

The head of the patient is not placed in side position but is turned halfway upward.

Figure *2A* shows the incision made by Popper through the skin. I make an incision that is more curved, with its convexity forward (fig. *2B*). This gives better cleavage. As will be noticed, the incision is extended a little down into the anterior part of the auricular lobule.

An approach is made at once to the cartilaginous part of the anterior wall of the external meatus, which is uncovered by means of an elevator (naturally, the perichondrium is preserved) down to the bony part of the anterior wall of the

meatus (the tympanic plate). These maneuvers imply no risk of injuring branches of the facial nerve or the parotid gland as long as the surgeon keeps close to the cartilage and bone.

Now a jaw lever is applied so that the mouth is kept wide open, as this gives more room for operating. Then, with a rectangular knife, the incision is made into the anterior wall of the meatus, separating the cartilaginous part of the wall from the bony part. The tragus plus the cartilaginous anterior wall of the meatus are pulled backward with a retractor. The periosteum is detached from the anterior aspect of the anterior wall of the bony meatus. Then the entire anterior wall of the bony meatus is removed by means of a rongeur, almost to the edge of the tympanic membrane.

Popper here sacrifices the cutaneous lining of the tympanic plate. In some of my cases a postoperative constriction of the meatus resulted from this procedure, and in 4 cases it even became necessary to reoperate almost in the form of a conservative radical operation. Therefore, I have sought to preserve the skin that

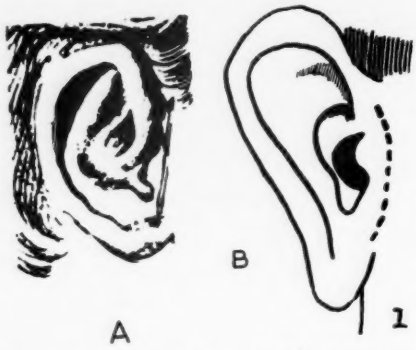

Fig. 2.—*A*, Popper's incision, made through the skin anteriorly to the tragus (after Popper [1]). *B*, Lund's incision.

lines the tympanic plate by elevating it before removing the tympanic plate with the rongeur. This skin is pressed forward against the periosteum from the bone removed, leaving a free view into the depth.

Now the inner half of the meatus is accessible to the full extent, leaving a "square-on" field of the posterior wall of the meatus and the tympanic membrane.

After this, Popper forms a tympanomeatal flap to be placed over the vestibular fenestra as follows: After the meatal integuments have been infiltrated with a procaine hydrochloride solution, an incision is made about 1 cm. from the tympanic membrane in all the remaining portion of the bony meatus clear down to the bone. This flap is detached together with the tympanic membrane for about two thirds of the circumference of the latter. To begin with, I also employed this method, but later I modified it, as it was found to be connected with a tendency toward postoperative constriction of the inner half of the meatus. So I adopted the following procedure, with which meatal constriction is sure to be avoided:

In the first place I do not infiltrate the skin in the depth of the meatus, as this procedure has proved to involve the risk that the tissue which marks the transition

between the meatal flap and the tympanic membrane at the annulus tympanicus may become fragile, with the result that a break of continuity may take place here, and such an accident would be rather annoying. Besides, this anesthesia is superfluous.

The flap is formed as shown in figure 4 *B*, where the area marked α forms the most internal part of the anterior wall of the meatus, and the area marked β is the most internal part of the upper posterior meatal wall. α shows the line of incision made at the formation of the anterior skin flap mentioned earlier. β is the skin flap that is to cover the vestibular fenestra; upward and posteriorly it is made 1 cm. broad, but downward in the posterior meatal wall it is narrowed considerably, and in the upper meatal wall it is narrowed somewhat anteriorly. Moreover, I do not detach the tympanic membrane to the large extent described by Popper. For

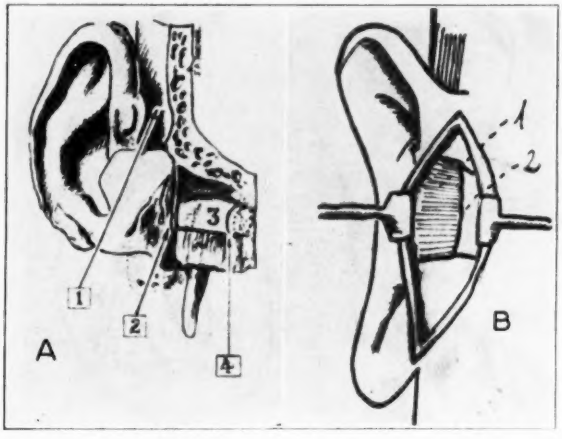

Fig. 3.—In *A* (after Popper [1]) arrow *1* indicates the incision illustrated in figure *2*. Arrow *2* indicates the second incision, made through the line along which the cartilage is attached to the tympanic plate. *3* locates the tympanic plate—removed. In *B* the cartilaginous part of the anterior wall of the external meatus is indicated by *1*; the pars tympanica, or tympanic plate, by *2*.

I have found it sufficient to loosen the area corresponding to incisura Rivini, i. e., the pars flaccida plus about *2* mm. of the pars tensa membranae tympani, just below the posterior tympanic spine—as indicated by the broken line above in the periphery of the tympanic membrane in figure 4 *B*.

After adopting these incisions my associates and I encountered no more instances of postoperative constriction of the meatus.

Now the meatal flap plus the pars flaccida is turned forward over the tympanic membrane as shown in figure 5; thus there is presented a "square-on" approach to the lateral bony wall of the attic.

Popper removes the lateral wall of the attic by cutting it down to a very thin barrier of bone by means of a burr and then removing this thin sliver. Without taking any risk, this step may be carried out more easily as follows: With a 2 mm.

burr a hole is drilled in the middle of the attic wall (fig. 5 *A*, α). Then the resulting "bridge" (fig. 5 *A*, β) is removed cautiously with a small straight chisel. The hole in the bony wall is widened by means of the chisel and a punch.

Here it may be mentioned that under these operations it has been my experience that the lateral bony wall is subject to rather wide variations, the extremes of which are given schematically in figure 6.

In figure 6 *A* the lateral bony wall (α) is seen to be almost vertical in relation to the upper wall of the meatus. In figure 6 *B* the wall of the attic is seen practically to continue in the upper wall of the meatus. In the first case the attic wall is thin and easily accessible; in the latter case it is thick and more difficult to work on with burr and chisel.

After the attic wall has been removed, the incus shows itself in the opening. By means of a fine periosteum knife it is detached from its articular connection with the

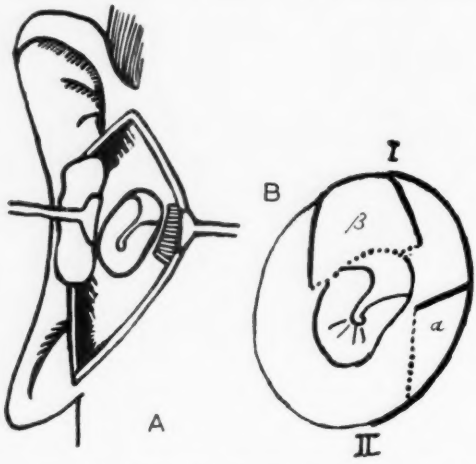

Fig. 4.—*A* shows the "square-on" presentation of the posterior wall of the external meatus and the drum. *B* shows the incision made through the skin that lines the anterior wall of the bony meatus (α) and that made through the skin that lines the upper posterior part of the bony meatus (β). The broken lines give the extent of the detachment of the margin of the tympanic membrane. The curved line *I—II* marks the incision of the anterior wall of the external meatus between the cartilaginous and the bony part.

head of the malleus and then removed. It is unnecessary to sever beforehand the articular connection between the crus longum incudis and the capitulum stapedis.

After the incus has been removed, the vestibular cupola shows above the distinct facial canal, and the fenestration is performed with the burr perpendicular against the cupola—without the least risk of injuring the facial canal.

Popper drills the fenestra in the vestibulum with a 2 mm. burr, which is applied just above the facial canal. The hole thus made is circular, with a diameter of 2 mm., the burr being held "rock-steady" on the drilling site. As Shambaugh has demonstrated experimentally that new formation of bone takes place from the outer periosteal bone of the labyrinthine capsule, I first remove the periosteal bone layer of the cupola. Then, by means of a 2 mm. burr, an elongated hole is made in the

most prominent part of the cupola. This hole is widened by means of a fine spatula or a periosteum knife, care being taken not to injure the labyrinthine endosteum under the edges of the fistula, as—according to Shambaugh—such an injury would have a tendency to bring about osteogenesis. The resulting fenestra is about 2.5 to 3 mm. long and about 1.5 mm. wide. Posteriorly in this fenestra, the ampulla of the lateral semicircular canal is seen; anteriorly a cistern of perilymph separates the saccule from the endosteum; hereby the membranous labyrinth is protected during the widening of the fenestra.

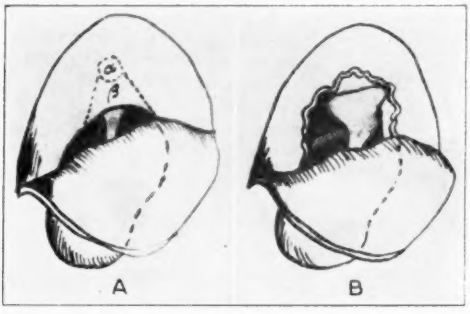

Fig. 5.—*A* shows the pars flaccida of the tympanic membrane plus the meatal flap reflected forward over the tympanic membrane. The crus longum incudis is seen in the depth. A hole is drilled in the lateral attic wall over the vestibular space (α). The "bridge" (β) is chiseled off.

B shows the hole of the lateral attic wall widened, the incus presenting. A relief of the facial canal is seen in the depth.

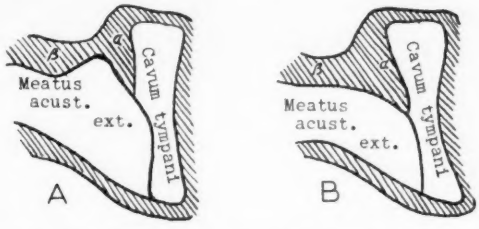

Fig. 6.—*A*, specimen in which the lateral bony wall of the attic (α) is almost vertical in relation to the upper wall of the meatus (β). *B*, specimen in which the attic wall is practically continued in the upper wall of the meatus.

Of course, while this drilling is performed the field is being continuously irrigated with Ringer's solution for the removal of the bone dust. *Under no conditions is suction to be applied directly to the fenestra opening*, as in that way the membranous labyrinth might be injured—an accident which occurred a few times in the earlier operations. In those cases the vestibular function was abolished in part, whereas the acoustic part of the labyrinth was not affected (thus there was no infection of the membranous labyrinth). After the drilling, the tympanomeatal flap is placed over the fenestra. The flap is kept in place by tamping it loosely with

ribbon gauze impregnated with Ringer's solution to which sulfathiazole and penicillin have been added.[2]

The cutaneous incision is sutured with silk or nylon. After a few weeks the scar anterior to the tragus is invisible.

The operation is performed with the patient under general anesthesia induced by intravenous injection of scophedal®[3] (about 0.6 to 1.5 cc.). Further, anesthesia

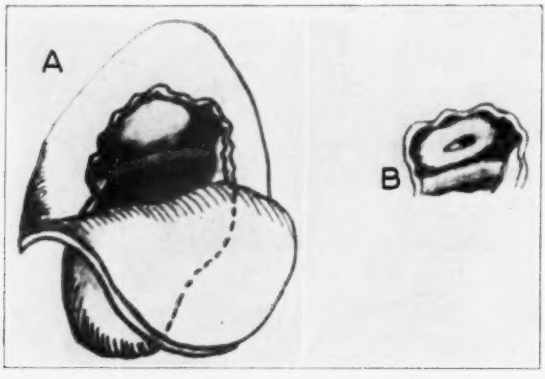

Fig. 7.—*A* shows the vestibular cupola presenting plainly above the distinct facial canal. In *B* the outer periosteal bone of the cupola has been cut off flat. Posteriorly in the oval fistula, the ampulla of the lateral semicirular canal is seen.

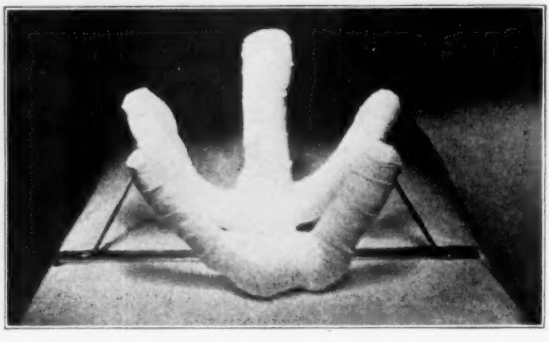

Fig. 8.—Head rest recommended by Shambaugh, use of which prevents any blood or exudate from entering the cochlea after operation

2. The sulfathiazole-penicillin solution is made as follows: 0.5 Gm. of sulfathiazole sodium and 10,000 Oxford units of penicillin dissolved in 10 cc. of Ringer's solution.

3. Scophedal is the trade name under which E. Merck, of Darmstadt, Germany, markets a solution containing in each cubic centimeter scopolamine hydrobromide 0.5 mg., dihydro-oxycodeinone hydrochloride (eukodal®) 10 mg. and racephedrine hydrochloride 25 mg.

of the entire vicinity of the external ear is obtained with subcutaneous infiltration of a solution of procaine hydrochloride containing epinephrine hydrochloride.

For two and one-half days prior to the operation the patient is prepared with sulfanilamide, 1 Gm. six times daily. After the operation this medication is continued, and in addition 300,000 units of penicillin is given daily. On the sixth day after the operation the medication is discontinued. The first change of bandage takes place six days after the operation, and after this the bandage is changed daily, gauze impregnated with sulfathiazole-penicillin–Ringer's solution being put in continuously. In two to five weeks the meatus will be lined with skin throughout.

After the operation the patient is placed in the bed with his face turned straight upward, and the head is fixed in this position by means of a padded iron frame as recommended by Shambaugh. The purpose of this is to avoid the possibility that blood and exudate may come from the site of the fistula into the cochlea, which with this position of the head lies above the vestibulum. As far as that goes, this arrangement is also agreeable to the patient, who is inclined to become dizzy on movements of the head.

ADVANTAGES OF POPPER'S METHOD

The advantages of the Popper operation, compared with the transmastoidal operation, are as follows:

1. The entire operation is performed under excellent survey, with "square-on" presentation of the posterior wall of the bony meatus. Thus the tympanomeatal plastic flap can be loosened easily and rapidly, without being preceded by the time-consuming thinning and removal of the bony wall of the posterior meatus.

2. The tympanic membrane has to be loosened only to a slight extent (even less than the extent given by Popper).

3. There is a "square-on" presentation of the site of fenestration in the vestibular cupola. The facial canal is sharply defined in the middle of the field, so that any injuring of this structure can be avoided with certainty.

4. The entire mastoid process is left intact—which also saves time.

5. The tympanic membrane does not have to be "stretched" as recommended by Lempert, because here the fistula is situated so far anteriorly that it is covered easily simply by laying the tympanomeatal flap down; moreover, the flap even extends out on the medial wall of the antrum.

6. It is unnecessary here to remove the head of the malleus—this is done in Lempert's method—because the plastic flap is sufficiently large to make the aforementioned "stretching" superfluous.

7. The operative trauma is considerably smaller than with the procedure given by Lempert.

On account of these considerable technical conveniences of the Popper method, the operation itself can be carried out in an hour and a half—unless some particular complication turns up, e. g., hemorrhage. Now and then one may accomplish it even more rapidly.

As mentioned, during my work with the Popper method I have found occasion to modify the Popper technic on five points.

ADVANTAGEOUS MODIFICATIONS OF POPPER'S TECHNIC

1. The skin on the inner surface of the anterior part of the osseous wall of the meatus—i. e., on the pars tympanica—is preserved.

2. The meatal flap is cut as an inverted "U," i. e., with its width corresponding to the attic wall.

Only when these two modifications are adopted may postoperative constriction of the meatus be avoided with certainty.

3. A technical advantage, even though less important, is the circumstance that the attic wall is perforated with the burr at once—instead of the slow drilling with the burr.

4. It is of not inconsiderable significance that the tympanic membrane has to be loosened only corresponding to the membrana flaccida and the spina tympanica posterior.

5. The change in the technic of drilling the vestibular cupola is of considerable importance; i. e., the periosteal layer of the bone is cut away corresponding to the site of the fenestration and its immediate surrounding.

After we had been applying this technic for nearly a year, we received, in Copenhagen, the number of the *Journal of Laryngology and Otology* issued in August 1946. This issue brought a new paper by Popper[4] concerning his operation, in which I noticed that during his further work he had found occasion himself to modify the technic on some points. Thus, Popper now employs the same technic that I do for removal of the attic wall.

He said further: "I have developed an important variation . . . which must be mentioned—but I do so with some hesitation," and he urged his inexperienced colleagues to follow the stages described in his first paper "with the beautiful landmarks as their constant guide."

This variation consists in making an inverted U-shaped flap of meatal skin covering the outer attic wall and in detaching the drum only in the area corresponding to Rivinus' incisure—i. e., just as I have done for the past year.

It is also interesting that Popper now removes the periosteal bone layer of the cupola in the same way that I have suggested.

I have been somewhat afraid that the cell system of the mastoid process might become infected in connection with the operation or subsequently. In the first case, therefore, roentgenologic examination of the temporal bone was performed before as well as some time after the operation. Only in 2 of 38 cases did roentgenography show a slight postoperative dimness of the mastoid cells. The 2 patients were operated on again because the meatus became constricted. A conservative radical operation was performed. The periantral cells and the cells of the mastoid tip were found to contain insignificant amounts of granulation tissue, which was undergoing organization; otherwise there were no inflammatory phenomena in the mastoid process. It is to be added

4. Popper, O. F.: J. Laryng. & Otol. **61**:441 (Aug.) 1946.

that such a conservative radical operation had to be performed on account of meatal constriction also in a case in which no inflammatory phenomena were found. In all 3 cases the improvement of the hearing was maintained.

MISHAPS

The following accidents have happened with this operation:

In 1 case the facial canal was denuded under the chiseling of the lateral attic wall, which resulted in facial paralysis of brief duration. In another case facial paralysis appeared five days after the operation and lasted a few weeks. The cause of this transitory paralysis could not be found.

In the first 4 cases in which I performed this operation, as mentioned before, the vestibular function was abolished in part, presumably on account of insufficient caution in the employment of the suction apparatus. In some additional cases the vestibular function was lowered but not abolished. For some little time the first 4 patients were troubled with dizziness and uncertainty of balance.

In 6 of the first 20 cases in which I myself or my assistants operated we had the misfortune to perforate the tympanic membrane. On the other hand, among the remaining 70 cases there was only 1 in which perforation occurred. The perforated membranes closed in all cases except 1. Perforation of the tympanic membrane causes considerable impairment of hearing . After healing of the perforated membrane the improvement due to the fenestration becomes the same as in cases without perforation.

Unfortunately, in 3 cases the meatal flap was torn entirely away from the tympanic membrane. In 2 of these cases it was placed in situ above the fenestra as a free graft, while in the third a Thiersch graft was laid. In 1 of these patients a chronic defect of the tympanic membrane resulted and there was no improvement of hearing. In the remaining 2 patients the perforated tympanic membranes healed, and the healing was followed by improvement of hearing. It is interesting to note that in the case in which transplantation was undertaken according to Thiersch the improvement of hearing still persisted after five months.

In 1 case the entire lateral membranous semicircular canal was removed by an unfortunate manipulation. This did not eliminate the caloric reaction, nor did it affect the cochlear portion of the ear. There was improvement from hearing at 0.40 meter to hearing at 16 meters for normal speech on examination two months after the operation. The case is of considerable interest from an experimental point of view, since it shows that with the modern chemotherapeutic agents being used as adjuvants, one can remove a single membranous semicircular canal without injuring the rest of the labyrinth. A further account of

this case is given in a subsequent article: Helmer Rasmussen's, entitled "Vestibular Function Prior to and Following Operation for Otosclerosis."

We have so far operated on 90 patients, using Popper's method. In 2 patients only was the operation followed by increased hardness of hearing, the hearing for normal speech having been reduced from 0.10 meter to *ad aurem*. This result shows the risk of impairment of the hearing to be so small that it can be left out of account in practice. Consequently, I intend in the future to operate on the ear with the best hearing when this is judged to be particularly profitable, and not, as usually, on the ear with the poorest hearing.

I have dwelt on the mishaps which we have experienced during our operations, and it appears from what has been stated so far that they are by no means discouraging. It is to be especially noted that infection of the labyrinth occurred in none of our patients. However, it should always be borne in mind that any surgical intervention involves a risk. We know from the literature that—very rarely, indeed—death has been recorded in consequence of the operation, even though the surgical intervention cannot be said to have been the direct cause of death. We have ourselves had a severe case. A pulmonary infarct developed during the postoperative confinement in bed, probably in consequence of phlebitis and, in addition, acute pyelonephritis and uremia. The patient recovered completely, however, after a long illness.

COMMENT ON RESULTS

Since a fairly long period of time must elapse after the operation before it is possible to pronounce with certainty on the final results with regard to the hearing, only a rather small number of the cases in which we operated can be used for an estimation of the results. This phase of the problem will be considered by Dr. Harald Ewertsen. Here it may only be mentioned that if we consider the fistula to be open when a positive fistula sign can be demonstrated, or if, when there is no fistula sign, real improvement of hearing has been demonstrated through the different acoustic tests, the fistula has, so far, become closed only in 7 of these 90 cases. This appears from table 1, comprising 62 patients on whom we have obtained information concerning this fact either in examinations made by one of us within a month or so prior to the time of writing or in other ways.

The table shows that 29 patients present a fistula sign and improved hearing, while 21 patients have improved hearing despite a failure to present a fistula sign; i. e. the fenestra has not closed. Five patients present a positive fistula sign but have nevertheless obtained no improve-

ment of hearing. Four of these were unfit for operation prior to surgical intervention, having had an aural range for normal speech of less than 0.10 meter. Seven have no fistula sign and unchanged hearing; in 2 hearing is even impaired. Thus the fenestra is open in 55 of 62 cases, i. e., in 89 per cent.

Results in 30 cases followed up for more than six months after the operation are recorded in table 2 (in 11 more cases we have no recent information).

It appears from table 2 that 25 of the 30 patients have an open fenestra. Thus 83 per cent have had an open fenestra for more than six months since the operation. (Of the 11 patients just mentioned, probably 8 or 9 have an open fenestra.)

TABLE 1.—*Results in 62 Patients Examined One to Thirteen Months After Operation*

	Fistula Test Positive	Fistula Test Negative	Total
Hearing improved	29	21	50
Hearing not improved	5	7	12
Total	34	28	62

TABLE 2.—*Results in 30 Patients Examined Six Months or More After Operation*

	Fistula Test Positive	Fistula Test Negative	Total
Hearing improved	12	10	22
Hearing not improved	3	5	8
Total	15	15	30

SUMMARY

An account is given of the technic of Popper's operation for otosclerosis as described in the *Journal of Laryngology and Otology* in 1946.

This operation, in which the initial incision is made anterior to the external auditory meatus, has been carried out on 90 patients with the following modifications of Popper's original technic.

1. The skin lining the wall of the anterior part of the bony meatus is preserved, the integuments being detached from the tympanic portion prior to the removal of the latter and subsequently used as a plastic flap.

2. The skin flap from the posterior bony meatal wall (the "meatal flap") is made far smaller than that recommended by Popper, being made 1 cm. long only above and posteriorly, and much narrower downward in the posterior meatal wall and forward in the superior meatal wall. Only by introducing these modifications can one be sure to avoid postoperative narrowing of the external auditory

meatus, a narrowing which may easily cause retention in, and possibly inflammation of, the mastoid cells.

3. The tympanic membrane is not detached to the extent indicated by Popper, but only over the area of the incisura Rivini including the posterior tympanic spine.

4. The lateral bony attic wall is removed in the following way: A hole is cut with a 2 mm. burr through the middle of the attic wall. Next the "bridge" thus developed is chiseled away. The hole in the attic wall is made larger with chisel and rongeurs. (The varying anatomic conditions of the lateral attic wall are described).

5. The cutting of the fenestra in the vestibular dome is not carried out as indicated in Popper's original publication but according to Shambaugh's method ("enchondralization"). The meatal flap is kept in situ after the operation by means of a strip of gauze soaked in sulfathiazole-penicillin-Ringer's solution (10 cc. of Ringer's solution containing sulfathiazole sodium, 0.5 Gm., and penicillin, 1000 Oxford units per cubic centimeter).

After the operation the patient is placed in the head supporter recommended by Shambaugh, with the head upright.

The advantages of the transtympanic over the transmastoidal operation are discussed:

1. The tympanomeatal flap can be detached easily and quickly, without wasting time by thinning and breaking down the posterior bony meatal wall.

2. The tympanic membrane is detached to a small extent only.

3. One gets a "square-on" view of the site of fenestration in the vestibular dome.

4. The facial canal stands out clearly.

5. The mastoid process is left intact.

6. It is unnecessary to remove the head of the malleus.

For these several reasons the operative trauma of Popper's procedure is far smaller than that of Lempert's operation. The Popper technic can be carried out more quickly and easily. There is no risk of infection of the cell system of the mastoid process when the skin of the mastoid process is treated as indicated in this article.

Among 90 operations carried out within the period between November 1946 to March 1948 there were only 2 failures with increased impairment of hearing. The fenestra has remained open in 89 per cent of the cases. Among the patients followed up more than six months after the operation 83 per cent have an open fistula. The results of investigations of the acoustic and the vestibular function carried out before and after the operation will be reported in the following articles by Dr. Helmer Rasmussen and Dr. Harald Ewertsen, respectively.

II. ACOUSTIC FUNCTION BEFORE AND AFTER OPERATION FOR OTOSCLEROSIS

HARALD EWERTSEN, M.D.

AN INVESTIGATION of the acoustic function is essential in the diagnosing of otosclerosis. In the present paper an account is given of tests made with tuning forks, monochord, whispered voice and speech as well as with the audiometer and possibly Fowler's test. None of these functional tests are ideal, and discrepancies are often experienced between the various tests.

Tuning forks and the monochord are not quite satisfactory when patients with impaired hearing are concerned.

Trowbridge,[1] who has for several years been doing routine hearing tests in the United States Army, using both tuning forks, speech and audiometer, stated that tuning forks can be usefully applied only with intelligent persons, but "the results were often confusing and contradictory, and precise conclusions could not be made from them alone."

The monochord is of importance for the fixing of the upper tone limit. Hall[2] holds that the assessment of the upper tone limit obtained by measuring bone conduction with the monochord "is a useful indication of the probability or otherwise of success" in the selecting of patients for operation, a fact which has been corroborated through our investigations.

Speech hearing tests, as Holmgren[3] pointed out, give great variations, many different factors being involved, such as the acoustic conditions of the room, the vocal pitch of the examiner, and the psyche and disposition of the patient. Practice and guessing will, moreover, play a part in repeated hearing tests, so that an apparent improvement may be noticed.

Fowler[4] maintained that the distance at which whispered voice or speech can be heard may present variations of up to 200 per cent, because among other reasons, the examiner is apt, quite unconsciously, to raise his voice at increasing distance from the patient.

Some of these difficulties have been overcome by using gramophone records for the hearing tests, with which the loudness of the reproduction of whisper or speech can be exactly regulated. However, this method also has certain disadvantages: The reproduction is not true to nature, the records become worn, and on repeated tests the patients will gradually learn the test words and their order of succession.

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1. Trowbridge, B. C.: Correlations of Hearing Tests, Arch. Otolaryng. **45**: 319 (March) 1947.

2. Hall, S. I.: J. Laryng. & Otol. **60**:201, 1945.

3. Holmgren, G.: Nord. med. (Hygiea) **100**:681 and 757, 1938.

4. Fowler, E. P.: Simple Method of Measuring Percentage of Capacity for Hearing Speech: Fundamental Factors in Setting up a Standard, Arch. Otolaryng. **36**:874 (Dec.) 1942.

Fowler [4] has ascertained that one need not distinguish each individual sound to be able to understand ordinary speech. To hear 70 per cent of the articulation is quite enough to catch the sense. To fulfil this requirement, ordinary speech must reach the ear with an intensity of not less than 30 decibels above the threshold value. It may, therefore, be understood that in a patient with impaired hearing a gain of 10 decibels is sufficient to change a number of incoherent sounds into intelligible speech.

It is a common experience that there is often a discrepancy between the audiogram and the result of the speech test. Thus, for instance, Kinney [5] wrote that the degree of impairment of hearing found by audiometry need not correspond to that ascertained at the speech test, because: pure tones (= audiometer) are not heard any better binaurally than with the best ear alone, whereas spoken voice is heard better binaurally than with the best ear only.

In audiometry the weakest audible intensity of a pure tone is registered, and the curve indicates the threshold of hearing but gives no information on that which is of the greatest importance for the patient's social adequacy, namely, his acuity of hearing above the threshold. Two persons with similar threshold audiograms may not hear speech alike. This is due to the recruitment phenomenon present in patients with nerve deafness but not in patients with a lesion of the conductive system. Fowler gives an instance of 2 patients, both with a threshold audiogram showing a loss of 40 decibels. Supposing that one patient has conductive deafness—he will not be able to understand speech till the intensity is 70 decibels, i.e., 30 decibels above the threshold, whereas the other, if he has nerve deafness, will be able to understand speech at 54 decibels, owing to the regression or recruitment.

The audiogram has so far given the best objective measure of changes of hearing acuity when the determination is made with the same apparatus and in the same noise-free room, and is carried out by an experienced examiner. There is, however, no doubt that the patient's experience and disposition influence the result. Harris,[6] by making repeated audiometric tests on a great number of patients, found the accuracy to be within 4.3 to 4.0 decibels at frequencies from 512 to 2048.

In otosclerosis the impairment of hearing is—as is well known—due to two different factors, a conductive factor and a perceptive lesion, depending as it does partly on the stapedial ankylosis and partly on an impairment of function of the end organ of hearing. The ankylosis has by far the greater share in the impairment of hearing, so that the audiogram presents a considerable difference between air conduction and bone conduction.

For prognostic purposes it is important that the value of the bone conduction, as an expression of the function of the cochlea, be ascertained, since by operation no greater improvement of the air conduction can be obtained than that corresponding to the existing degree of bone conduction. However, Lempert [7] pointed out that neither the bone conduction values found with tuning forks nor those obtained with the audiometer give fully reliable measures for the function of the end organ of hearing, partly because of transmission of sound to the better ear and partly because of recruitment.

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5. Kinney, C. E.: Laryngoscope **55**:117, 1945.

6. Harris, J. D.: Free Voice and Pure Tone Audiometer for Routine Testing of Auditory Acuity: Studies on Comparative Efficiency, Arch. Otolaryng. **44**:452 (Oct.) 1946.

7. Lempert, J.: Lempert Fenestra Nov-Ovalis with Mobile Stopple, Arch. Otolaryng. **41**:1 (Jan.) 1945; cited by Fowler, E. P.: Otosclerosis: An Index of Literature, with Abstracts, for 1944-1945, ibid. **45**:215 (Feb.) 1947.

Walsh and Silvermann [8] likewise hold that bone conduction is no reliable expression of cochlear function, because the thickness of the bone, the degree of its pneumatization and the condition of the mucosal lining influence the degree to which sound waves are conducted through the bone. ("Bone conduction tests in many cases are unreliable. We pay little attention to them and use them only for general screening.")

The conclusion is that there is not yet an exact test for acoustic function to indicate the degree of the auditory nerve's degeneration, so that—on the assumption of a technically successful operation—one cannot yet settle the prognosis with regard to the patient's postoperative acuity of hearing. Holmgren [9] has given an illustrative example: The patient prior to operation presented a bone conduction threshold of 70 decibels and an air conduction threshold of 90 decibels at the frequency of 2000 cycles, and accordingly there would seem to be contraindication for operation. However, the patient presented a postoperative improvement of the bone conduction threshold to 5 decibels and of the air conduction threshold to 35 decibels, and the patient had obtained hearing for speech at a distance of 10 meters, compared with *ad aurem* hearing two years previously.

MATERIAL

The observations to be reported were made on the first 85 patients operated on in the ear department of the Sundby Hospital, Copenhagen, beginning Nov. 8, 1946—within about seventeen months prior to the time of writing.

The diagnosis of otosclerosis and the selection of the patients were based on the following criteria: past history, otoscopic examination, investigation of acoustic and vestibular functions, roentgenographic study. In estimating the material it should be borne in mind that the indications for operation were not particularly strict, because (1) the risk of further impairment of hearing is small, (2) the ear with the poorest hearing acuity has always been operated on, and (3) patients, even those with excessive hardness of hearing, have a chance of obtaining considerable improvement of hearing acuity.

Of the 85 patients, one third were men and two thirds were women, a sex incidence which accords with that of other statements.

The ages of the patients ranged from 22 to 67, with an average of 45 years.

The defect of hearing had persisted for from five to forty-five years, and had first been noticed by the patients at some time within the period from the age of puberty till about the end of the thirties, in most cases within the twenties. About 60 per cent of the patients had used a hearing aid prior to the operation.

OBSERVATIONS

Paracusis.—In addition to hardness of hearing and tinnitus, numerous otosclerotic patients report a subjective phenomenon called paracusis willisiana, which means that the patient's hearing is better in noise (e. g., train, tram or factory) than under quiet conditions.

8. Walsh, T. E., and Silvermann, R. S.: Laryngoscope **56**:536, 1946.
9. Holmgren, G.: Nord. med. **37**:151, 1948.

This is, according to Voss,[10] due to a thiotropy, i. e., the power of certain gels to be liquefied by intense shaking, after which they return to their original consistency. Wood[11] succeeded in making thiotropic gels liquid by the action of sound waves of high frequency.

Fifty-eight of the patients were questioned about this symptom. Thirty-four answered in the affirmative, while 24 had observed no such symptom. In other words, 59 per cent of these patients had experienced paracusis. This is, therefore, a rather important symptom, the more so because all other forms of deafness are extremely rarely found associated with paracusis.

Diplacusis.—Among 38 patients questioned 1 patient stated that diplacusis (for deep tones only) had been noted.

Tinnitus.—This is a symptom commonly associated with otosclerosis. Only 8 of 70 patients had never had a subjective noise in the ears. Lempert stated that tinnitus ceased in 95 per cent of his successful operations. Among the present patients the tinnitus was as shown in table 1.

TABLE 1.—*Tinnitus*

Prior to Operation—70 Patients	Following Operation—53 Patients
25, pronounced tinnitus	28, unchanged tinnitus
37, varying or light tinnitus	15, cessation of tinniuts *
8, no tinnitus	6, reduced tinnitus
	4, aggravated tinnitus

* Tinnitus ceased in 15/53, or 29%

Acuity of Hearing.—Acuity was assessed on the basis of whisper and voice tests, audiometry, tuning-forks and monochord tests and the patients' own statements.

There are many ways in which to estimate acuity of hearing. I shall point out here only the most important.

It is the patient's hearing of speech which is the decisive factor for his social adaptation. Moreover, the speech test has proved, despite its drawbacks, to give a serviceable measure of the patient's loss of hearing.

The room in which the tests were performed was 15 meters long and had a somewhat varying noise level. The voices of the different examiners gave varying results; yet the variation was within fairly narrow limits, so that classification of the patients was possible (see table 2). In order to counteract the unconscious inclination to raise

10. Voss, O.: Med. Welt **13**:1011, 1939; cited by Fowler, E. P.: Otosclerosis: An Index of the Literature with Abstracts, for 1944-1945, Arch Otolaryng. **45**:215 (Feb.) 1947.

11. Wood, cited by Voss.[10]

the voice at increasing distance from the patient, I performed each test with closed eyes and concentrated on speaking in the same intensity of voice throughout.

Of the 85 patients, 69 have been kept under observation for from one to thirteen months since the operation. The speech tests gave the results indicated in table 2. Two showed slight deterioration (from 3 to 1 meter and from 0.20 to 0.10 meter); in 11 hearing was unchanged; in 16 hearing was somewhat improved and in 40, i. e., 58 per cent, hearing was definitely improved (V $\geqq$ 4 meters).

Within the group capable of hearing voice at a distance of 10 cm. or less only 18 per cent obtained definite improvement. Hence this upper group must be regarded as unfit for fenestration.

TABLE 2.—*Results of Speech Tests of 69 Patients Made Before and After Fenestration* *

Hearing Distance Before Operation	Patients	Hearing Distance After Operation: Ad Aurem	to 0.10 M.	0.20 M.	0.50 M.	1-2 M.	4 M.†	8 M.	12 M.	>15 M.	Proportion of Patients Definitely Improved	
Ad aurem (shout).	1	..	..	1	..	..	..	..	..	0 of 1		
Ad aurem to 0.10 M.	21	2	8	5	2	**2**	**1**	**1**	..	4 of 21		18%
At 0.20 M.	23	1	2	1	3	**3**	**5**	**1**	**7**	16 of 23		
At 0.50 M.	11	..	..	..	2	..	..	**4**	**5**	9 of 11		
At 1.00 M.	3	..	..	..	1	..	**1**	..	**1**	2 of 3		
At 2.00 M.	4	..	..	..	..	..	**3**	..	**1**	4 of 4		77%
At 4.00 M.	1	..	..	..	1	..	..	..	..	1 deteriorated		
At 8.00 M.	5	..	..	..	..	..	..	**3**	**2**	5 of 5		
Total	69	3	10	7	9	**5**	**10**	**9**	**16**	40 of 69 =		58%

Age Incidence

In the upper group 13 of 43 = 30 per cent were under 45 years old
In the lower group 19 of 26 = 73 per cent were under 45 years old

* The periods of observation ranged from one to thirteen months.
† Bold face figures indicate safe improvement.

The age incidence bears out the theory that otosclerosis is a disease which progresses with increasing age. Thus, the patients of the group proving to have been the least fit for operation were also the oldest. If we set the limit at the average age of 45 years, only 30 per cent were under 45 years of age in the upper group, against 73 per cent in the lower group.

If stricter limits had been set for the indications for operation and the least fit group, comprising 22 patients, had been excluded, 47 patients would have been left, of whom 36, i. e., 77 per cent, obtained definite improvement.

This again means that hearing for speech is not a bad indicator of the result to be expected from operation. If the patient has hearing for voice at 10 cm. or less (V $\leqq$ 10 cm.), there is only 18 per cent chance of definite improvement, whereas there is 77 per cent chance of

definite improvement when there is hearing for voice at 20 cm. or more ($V \geqq 20$).

On the other hand, hearing for voice at 10 cm. or less is no contraindication for operation, some patients obtaining considerable improvement of hearing. I have therefore tried to find out whether any of the other hearing tests can give a hint as to the prognosis. Table 3 presents the average determinations for 22 patients with preoperative hearing for voice at 10 cm. or less. Of these patients,

TABLE 3.—*Results of Preoperative Tuning Fork, Fowler and Monochord Tests of 22 Patients with Preoperative Hearing for Voice at 0.10 Meter or Less*

Group	Average Age	Tuning Fork Test: Air a_1	Tuning Fork Test: Bone a_1	Fowler's Test: Bone	Fowler's Test: Air	Monochord Test: Air	Monochord Test: Bone
11 patients with hearing improved to V = 7 M.	48	4″	13″	55 db.	90 db.	0	16,000
11 patients with unimproved hearing.....	52	3″	14″	56 db.	88 db.	0	10,000

The third column shows the average vibration time in seconds for tuning fork a_1, measured partly by air conduction and partly by bone conduction (normal = 60″ and 30″).

The fourth column contains the average decibel values calculated according to Fowler, partly by bone conduction and partly by air conduction.

In the last column the average values have been set out for the upper tone limits by air conduction and by bone conduction, measured with the monochord.

TABLE 4.—*Results of Speech Tests of 30 Patients Six to Thirteen Months After Fenestration*

Preoperative Hearing Distance	Patients	Postoperative Hearing Distance: Ad Aurem to 0.10 M.	0.20 M.	0.50 M.	1-2 M.	4 M.*	8 M.	12 M.	15 M. or More	Safe Improvement
Ad aurem to 0.10 M.....	10	5	1	..	..	..	1	1	**2**	4 of 10
0.20 M.....	9	..	1	..	1	1	1	..	**5**	7 of 9
0.30-1 M.....	5	..	..	1	1	..	..	1	**2**	3 of 5
1 m.-3 M.....	3	..	..	..	1	..	1	..	**1**	2 of 3
4.00 M.....	1	..	..	..	..	..	..	..	**1**	1 of 1
8.00 M.....	2	..	..	..	..	..	..	..	**2**	2 of 2
Total.....	30									19 of 30 = 63%

* Bold face figures indicate safe improvement.

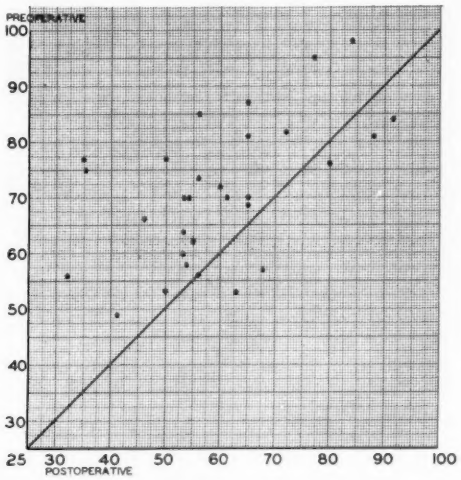
11 obtained more or less improvement of hearing (averaging V = 7 M.) while in the remaining cases the hearing remained unchanged or was slightly worse.

The two groups were compared with regard to age, hearing acuity measured with tuning fork a_1 and the bone and air conduction values obtained with monochord and audiometer. The values for the lower limit were difficult to calculate, but they seem to have been identical in the two groups.

Only the average values have been recorded in table 3. It appears from these figures that the two groups of patients presented no dif-

ferences with regard to average age, hearing acuity measured with tuning fork a_1 or level of audiometer curves. But the preoperative value for the upper tone limit of bone conduction measured with monochord was essentially higher for the group of improved patients than for the patients who obtained no improvement of hearing. This observation bears out Hall's previously mentioned experience.

Forty-one patients were operated on more than six months ago. We still have contact with 30 of these patients. In 1 patient hearing has slightly deteriorated; in 8 hearing is unchanged; in 2 hearing is slightly improved; in 19 i. e., 63 per cent, hearing is definitely improved.



Air conduction values of 30 patients according to Fowler's test. The ordinate indicates the preoperative value in decibels, and the abscissa the postoperative value measured from six to thirteen months after the operation. Eighteen of the 30 patients, i. e., 60 per cent, have obtained improved hearing.

By leaving out again the least fit group, comprising 10 patients, with a hearing for speech less than 0.10 m. there are 20 patients left, of whom 15, i. e. 75 per cent, obtained definite improvement.

The fistula sign changed in 7 patients from positive to negative in the course of from six to thirteen months after the operation, but in 3 of these the acuity of hearing is still improved. This means that the fistula closed within six to twelve months after the operation in 4 of the 30 patients, i. e. 13 per cent. By way of comparison the percentages reported by some others may be stated: Lempert had 140 among 1,000 (14 per cent), Shambaugh 51 among 800 (6.5 per cent), Day 10 among

100 (10 per cent), of whom 9 were among his first 50 patients (18 per cent)—in other words, figures corresponding to those of the present group.

In the chart I have set out in diagrammatic form the air conduction values calculated according to Fowler's test.

The audiometer in the Sundby Hospital is a radiometer* product of rather fine calibration. Three examiners have each studied 7 young persons in whom otoscopic examination showed normal conditions and have generally found thresholds of about 5 to 10 decibels where the thresholds ought to be on the zero line. The results of our measurements have to be corrected upward by about 10 decibels to correspond with the measurements of other authors.

All the values grouped about the axis at a distance of up to ± 5 decibels are regarded as unchanged (10 patients). In 2 cases the values lie somewhat below the axis, thus showing slight deterioration. Eighteen,

TABLE 5.—*Shifts of Tone Limits*

		Fenestra		
		Open	Closed	Total
Shift of lower tone limit	up	1	..	1
	unchanged	3	..	3
	down	9	2	11
Total		13	2	15 patients
Shift of upper tone limit	up	7 (2)	1	8 (3)
	unchanged	2	..	2
	down	11 (2)	3	14 (5)
Total		20 (4)	4	24 (8) patients

i. e. 60 per cent, whose values lie above the axis, have obtained improved hearing. Thus, there is agreement between the results obtained by audiometry and those obtained by speech tests. However, none of these patients has achieved a threshold of hearing better than 30 decibels by air conduction.

The bone conduction values before and after operation have in these 30 cases remained fairly constant within the range of error of ± 5 decibels. But in 4 cases an improvement was shown in bone conduction of from 14 to 20 decibels. The requirement often made by American investigators of a preoperative bone conduction threshold better than 30 decibels within the speech range is in our opinion too strict, this requirement having been fulfilled by only one of the patients here reported on.

Moreover, mention will be made here of the shifts of upper and lower tone limits. The shift of the lower tone limit following the operation was controlled in 15 cases: In 1 it was raised (from 30 to 65 cycles); in 3 it remained unchanged, and in 9 it was depressed, in some of them as far down as 16 cycles.

The shift of the upper tone limit was controlled with the monochord in 24 cases and compared with the improvement of hearing and the fistula sign. Shambaugh found no depression in his material, and he holds that depression of the upper limit is indicative of serous labyrinthitis, affecting chiefly the upper tone limit.

Holmgren, on the other hand, regards a depression of the upper tone limit as due to reduced intralabyrinthine pressure.

In the present series the upper limit had become raised (measured either by bone conduction or by air conduction) in 8 cases and depressed in 14; it remained unchanged in 2. The percentage distributions of hearing improvement and fistula sign are alike for these groups.

I shall finally conclude this article with mentioning that Rinne's test was controlled after the operation in 19 of 69 cases. In 12 cases it still showed that bone conduction was better than air conduction. One explanation for this, among others, is that not only the air conduction but also the bone conduction at this frequency had been prolonged by the operation. For the remaining 7 patients the Rinne test showed that air conduction was better than bone conduction.

III. VESTIBULAR FUNCTION PRIOR TO AND FOLLOWING OPERATION FOR OTOSCLEROSIS

HELMER RASMUSSEN, M.D.

IN THE present article the results of vestibular investigations will be presented for 79 of the 88 patients operated on for otosclerosis according to Popper's method in the ear department of Sundby Hospital between November 1946 and April 1948.

Of the 79 patients, the majority, 51, were in their thirties and forties, while 5 were in their twenties, and 23 in their fifties and sixties. Thirty-one were men, and 48 were women.

VERTIGO

Concerning 67 the presence or absence of vertigo prior to operation was known; 18, i. e., 27 per cent, had been suffering from more or less pronounced vertigo. This figure accords with Nager's [1] findings. Of his patients, one fourth to one third complained of vertigo, without physical vestibular disturbances being demonstrable.

After the operation 15 patients were completely free from vertigo, while in the remaining 64 patients more or less disturbing vertigo persisted for a shorter or longer time, as appears from table 1.

In 7 of the 13 patients with protracted vertigo the symptom was still present at the latest follow-up. Those with protracted vertigo belong chiefly to the first half of this series, a fact which indicates that the technic used has gradually improved.

SPONTANEOUS NYSTAGMUS

Spontaneous nystagmus was demonstrated following the operation in all cases except 4. The duration of the nystagmus appears from table 2. The direction of the nystagmus was exclusively toward the normal side in 35 cases and exclusively toward the side operated on in 1 case. In the remaining cases the direction varied between the normal side and the side operated on—or the nystagmus was undulatory. The direction would often change within the same day.

Brunner,[2] on the other hand, arrived at a different result so far as he found that the eyeballs rolled toward the side not operated on

1. Nager, F. R., in Fowler, E. P.: Medicine of the Ear, New York, Thos. Nelson & Sons, 1939, p. 261.

2. Brunner, H., and Cutler, M. H.: Labyrinthine Symptoms Subsequent to Fenestration of Labyrinth, Arch. Otolaryng. **45**:613 (June) 1947.

within the first twenty-four hours after operation but that after twenty-four hours the nystagmus changed, being either directed toward the side operated on or undulatory. The nystagmus would generally subside in the course of three or four days.

In some cases, after spontaneous nystagmus was no longer observed with the patient in the dorsal or the upright position, nystagmus could be demonstrated when the head was bent sideways or forward or backward. However, no great importance should be attached to this phenomenon, as it was no doubt a vascular fistula sign in several of the cases.

NYSTAGMUS PRODUCED BY FISTULA TESTS

Fistula tests were made on all the patients except 2, partly by pressing directly against the site of the fistula and partly by compressing and

TABLE 1.—*Vertigo After Operation (79 Patients Investigated)*

Duration of Vertigo	Patients
No vertigo	15
1 to 3 days	24
4 days to 2½ wk.	27
1 to 15 mo.	13
Total	79

TABLE 2.—*Spontaneous Nystagmus After Operation (79 Patients Investigated)*

Duration of Nystagmus	Patients
No spontaneous nystagmus	4
1 to 7 days	42
1 to 4 wk.	27
1 to 9 mo.	5
Total	79

decompressing the air of the external meatus with a bulb. Furthermore, examinations were made for the vascular fistula sign by compressing the jugular veins from the right and from the left side alternately, as well as from both sides simultaneously, and after inhalation of amyl nitrite. Finally, fistula tests were made during the first few days after the operation, i. e., before the dressing was changed, by pressing against the dressing.

The fistula test was generally made the first time the dressing was changed, and then repeated at regular intervals.

The results of the tests appear in table 3. In 2 cases the fistula sign was not looked for. In 13 cases all fistula tests gave negative results, while in 7 cases the fistula sign could be produced only during the first few days after the operation by pressing against the dressing, whereas the rest of the fistula tests gave negative results.

Furthermore, it appears that if the fistula has not closed after six months, the chance of its remaining open is great, as the fistula closed in only 1 of the 17 cases in which more than six months had elapsed after the operation.

A comparison between direct pressure and compression made in the external auditory meatus for eliciting the fistula sign showed the sign to be positive longest by comparison in 16 cases and longest by direct pressure in only 1 case.

The direction of the nystagmus appears from table 4. In all cases the nystagmus was lateral or lateral-rotary, or mixed lateral and lateral-rotary, but never rotary alone. It may be added that the fistula sign was regular in all the 7 cases in which the sign could be elicited only by

TABLE 3.—*Fistula Sign After Operation*

Number of Months After Operation	Patients in Whom Sign Was Still Present	Patients in Whom Sign Later Disappeared	Total
¼ to ½	8	5	20
½ to 2	7		
2 to 6	15	5	20
6 to 15	16	1	17
Total	46	11	57

TABLE 4.—*Directions of Nystagmus at Fistula Tests*

Test	Patients Presenting Given Type of Nystagmus		
	Regular	Reverse	Mixed
Pressure directly over fenestra	40	2	10
Compression in external canal	38	4	10
Decompression in external canal	26	7	8

pressing against the dressing, (i. e., during the first days after the operation).

In a few cases the direction of the nystagmus differed with the different methods of testing. Thus, direct pressure elicited regular nystagmus and compression in the external meatus elicited reverse nystagmus in 3 cases, whereas the opposite directions were seen in 2 cases. In 6 cases the eyeballs rolled toward the side operated on both with compression and with decompression. In 3 of these the eyeballs later rolled toward the side operated on with compression and toward the opposite side with decompression. The reverse phenomenon (i. e., nystagmus toward the side not operated on both with compression and with decompression) was not observed.

In 76 cases tests were made for the vascular fistula sign by compression of the jugular veins, and in 13 cases, by inhalation of amyl nitrite.

Compression of the jugular veins produced a fistula sign in 30 of the 76 cases, and amyl nitrite, a positive sign in 6 of the 13 cases. This result contrasts with that arrived at by Brunner,[2] who in none of 24 cases of fenestration demonstrated a vascular fistula sign by pressing against the carotid artery.

The sign was in no case positive on compression of the jugular veins and negative on inhalation of amyl nitrite, whereas the reverse was observed in 5 cases.

On compression of the jugular veins the sign was regular (i. e., the nystagmus was directed toward the side not operated on) in 9 cases and reverse (i. e., the nystagmus was directed toward the side operated

TABLE 5.—*Direction of Nystagmus on Compression of Jugular Veins and Inhalation of Amyl Nitrite*

Test	Patients Presenting Given Type of Nystagmus			
	Regular	Reverse	Mixed	Undulatory
Compression of jugular veins (30 patients)	9	13	7	1
Inhalation of amyl nitrite (6 patients)	1	5	..	..

TABLE 6.—*Duration of the Vascular Fistula Sign as Observed in the 30 Patients in Whom It Was Obtained by Compression of the Jugular Veins*

Number of Months After Operation	Patients in Whom Sign Was Still Present	Patients in Whom Sign Later Disappeared	Total
Up to 2	7	8	15
2 to 6	8	2	10
6 to 10	5	..	5
Total	20	10	30

on) in 13; in 7 it was alternately regular and reverse, and in 1 case the nystagmus was undulatory. In other words, the fistula sign was reverse or alternately regular and reverse in two thirds of the cases (table 5).

The amyl nitrite sign was in 1 case regular (i. e., the nystagmus was directed toward the side not operated on) and in 5 cases reverse (i. e., the nystagmus was directed toward the side operated on) (table 5).

The amyl nitrite test was performed only once on each of the examined patients. The reason for this as well as for the fact that the test was not made on the remaining patients was simply that no more amyl nitrite could be procured.

The jugular vein test, on the other hand, was made several times. The results of these repeated tests appear from table 6. It is seen that in several patients the sign was still positive long after the operation, at a point of time when the area of operation had healed completely, and

when, accordingly, no granulation tissue could be expected to be present in the fistula. Therefore the sign can hardly have been due to changes of volume because of hyperemia of granulation tissue here, but must have been due to changes of pressure in the labyrinth because of increased volume of blood in the latter or to intracranial changes of pressure affecting the labyrinth by way of the saccus endolymphaticus.

NYSTAGMUS PRODUCED BY ROTATION

Two patients were not submitted to rotation tests prior to the operation. On 28 patients the preoperative tests were made only with the patient in the upright position, while on the remaining 49 the tests were made with the patient in the upright position and with the head bent to the right and to the left, as well as forward and backward.

One patient was not submitted to rotation tests after the operation. Postoperative rotation tests were made on the remaining patients with the head in the different positions. In 45 cases the tests were performed first one to two weeks after the operation, in 20 cases two to three weeks, and in 13 cases three weeks to five months after the operation.

In each position five rotations were carried out to each side within about ten seconds.

Rotation with the Patient in Upright Position.—Prior to Operation: It is a matter of no small interest that in 6 patients the postrotatory lateral nystagmus was of short duration, less than ten seconds, prior to the operation. In one of these patients abnormal conditions were demonstrated also for the postrotatory rotary and vertical nystagmus. In another patient the duration was sixteen seconds to one side, but forty-nine seconds to the other—in other words, a difference of more than 50 per cent.

The foregoing facts show that the vestibular apparatus was affected in these 7 patients. This is only what might be expected, since well over one fourth of the entire series reported subjective vestibular disturbances, namely, vertigo.

After Operation: In 12 patients with normal duration of the postrotatory lateral nystagmus prior to the operation there was now found a duration of less than ten seconds for the postrotatory lateral nystagmus released from the side operated on. However, in none of these patients was the duration of the nystagmus released from the side operated on less than half of that released from the side not operated on, which was likewise short, twelve seconds at most.

These findings suggest that there is reduced function of the horizontal canal on the side of operation, due to a minor damage in consequence of the operation. Likewise, it is suggested that compensation has occurred on the side not operated on.

In 8 patients, 7 of whom were examined one to three weeks and the eighth two and a half months after the operation, the duration of the nystagmus released from the side operated on was found to be less than half of that released from the side not operated on, and the longest duration was eleven seconds. In 3 of these patients no nystagmus whatever was released from the side operated on. One of the 8 patients was the one previously described in whom prior to the operation nystagmus was released from the ear to be operated on for sixteen seconds and from the other ear for forty-nine seconds, a fact which is suggestive of reduced function of the horizontal canal. Following the operation, the durations were five and thirty-two seconds, respectively, showing complete loss of function of the canal.

In 9 more patients the duration of the nystagmus released from the ear operated on was found to be equal to or under half of that of the nystagmus released from the other ear. As, however, these patients presented spontaneous nystagmus toward the side not operated on, the lack of response to rotation stimulus of the labyrinth on the side of operation cannot be regarded as definitely pathologic.

Thus, in only 8 cases can the horizontal canal be said for certain not to have responded to the rotation stimulus.

Subsequent tests showed the postrotatory reaction to have become normal in 6 of these 8 cases. In the seventh nystagmus was released only for six seconds from each side. Thus compensation had occurred on the side not operated on. In the eighth case the membranous horizontal canal had been removed during the operation, and in this case no reaction could be elicited from the side of operation, neither at the first nor at the second test which was made on the fiftieth day after the operation. Compensation occurred here, too, since the nystagmus released from the side not operated on lasted twenty-five seconds at the former test and only five seconds at the latter. Here we have a purely experimental corroboration of the laws concerning the postrotatory nystagmus of the patient in the upright position.

So in 8 cases the horizontal canal was damaged during the operation, but in 6 of these the damage proved to be reparable. To pronounce with certainty on the nature of the damage is, of course, difficult except in the case in which the membranous horizontal canal was removed during the operation, but most likely the pathologic alteration was purely mechanical or was caused by hemorrhage. It was hardly the result of infection.

In 2 cases the nystagmus released from the side operated on was directed obliquely downward, probably because of the demonstrated spontaneous nystagmus directed to the side not operated on.

In 5 cases the lateral nystagmus released from the side of operation was, peculiarly enough, combined with a rotary nystagmus to the

opposite side. In one of these a similar combination was found to be released from the side not operated on.

Finally, there is reason to mention that in 5 cases the duration of the nystagmus released from the side not operated on was under half of that of the nystagmus released from the side of operation. In one case the difference was particularly great—four and forty-three seconds, respectively—and in another no nystagmus whatever was released from the side not operated on. This was no doubt due to a tendency of nystagmus toward the side that was operated on.

Rotation with the Patient's Head Bent Forward or Backward.—Rotation with the head of the patient bent forward or backward brings about rotary nystagmus, which is released from the superior and posterior canals on the side to which the nystagmus is directed. Prior to the operation 49 patients were tested for rotary nystagmus. In 2 no rotary nystagmus could be brought about in one of the positions (in one case no rotary nystagmus to one side, and in the other, neither to one side nor to the other), probably on account of a lesion in the vestibular apparatus. In one of these cases also the postrotatory lateral and vertical nystagmus presented abnormal conditions.

After the operation the rotary nystagmus was absent in several patients, mainly that released from the side of operation. If we leave out of account the patients in whom there was spontaneous nystagmus on examination, the rotary nystagmus released from the side operated on was absent in 12 patients, either with the head bent forward or backward, or in both positions. In all these patients the conditions were normal before the operation. The rotary nystagmus released from the side not operated on was absent in 1 patient in both positions; and in 2 patients both that from the side of operation and that from the opposite side were absent in one or in both positions. In these 3 patients with disturbances on the side not operated on, or on both the side of operation and the side not operated on, the conditions were normal on subsequent examinations.

Of the 12 patients with disturbances exclusively on the side of operation subsequent tests showed pathologic conditions persisting in 1 patient only, whereas the reaction was normal in the remaining 11 patients.

The observations described suggest that there were disturbances of the function of either the superior or the posterior canal or both canals in these patients. In most of them these disturbances were, however, transitory only.

Rotation with the Head Bent to the Right or to the Left.—Rotation with the head bent to the right or to the left brings about vertical nystagmus. The downward directed vertical nystagmus is released

from the two superior canals and the upward directed vertical nystagmus from the two posterior canals.

Forty-nine patients were tested for vertical nystagmus prior to the operation. In 2 patients the upward directed vertical nystagmus could not be elicited with the head either on the right or on the left shoulder, presumably on account of vestibular disturbances. In one of these patients also the postrotatory lateral and rotary nystagmus presented abnormal conditions. After the operation the upward directed vertical nystagmus was absent in 4 patients without spontaneous nystagmus in the position concerned—in 2 patients in one position only and in the other 2 in both positions. In 1 of these 4 patients the same pathologic conditions were present also before the operation. Finally in some patients (in part with spontaneous nystagmus) the released nystagmus had an oblique direction.

A total of 15 patients presented abnormal conditions of postrotatory nystagmus released from the vertical canals. Slight or more pronounced changes of the postrotatory lateral nystagmus were demonstrated in 7 of these patients.

TABLE 7.—*Abnormalities of Postrotatory Nystagmus*

Type of Nystagmus	Patients Presenting Abnormal Reactions
Prior to Operation	
Lateral (77 patients)	7 *
Rotary (49 patients)	2 *
Vertical (49 patients)	2 *
After Operation (78 Patients)	
Lateral	12 (slight changes) 8 (pronounced changes)
Rotary	12
Vertical	4

* In 1 patient there were abnormalities of all three directional types of nystagmus.

Table 7 illustrates the results of the rotation tests, part of which were made before and part after the operation.

NYSTAGMUS PRODUCED BY THE CALORIC TEST

Before Operation: The caloric test was made prior to the operation on all patients except 2. One hundred cubic centimeters of water, at 10 to 15 C., was applied for the test. In 27 cases the test was made only with the patient in the upright position and with the head bent forward, while in the remaining 50 cases it was made also with the head bent to the sides and backward.

Five patients reacted abnormally before the operation. In 3 the released nystagmus ceased when the head was bent forward; in a fourth a purely rotary nystagmus to the opposite side was seen with the head bent forward, and in the fifth the nystagmus became vertical

downward in the forward bent position, and in this case the nystagmus ceased when the head was bent backward.

After Operation: All the patients were tested except 3. On 43 patients the test was made first one to two weeks after the operation, on 15 patients two to three weeks after, while on the remaining patients it was not made till between three weeks and six and one-half months after the operation. The test, which was generally made with insufflation of air, was carried out several times, and the reactions were observed with the patient's head in the different positions.

The test revealed abnormal conditions in 48 of 76 patients. Four of the 48 patients reacted abnormally also before the operation. In 30 of these 48 patients the reactions were normal except for a lack of change of the lateral nystagmus in the forward bent position of the head. One of these patients was the one mentioned whose membranous horizontal canal had been removed during the operation. Subsequent performances of the test gave change of the lateral nystagmus at forward bending in no more than 3 of the patients. In another patient the test when made the first time, seventeen days after the operation, showed change at forward bending of the head, but not when made the second and the third time, five and eleven months, respectively, after the first.

Twelve of the 48 patients presented other abnormal reactions. In 8 the nystagmus could be released only in certain positions; in 2 the nystagmus was only lateral or rotary, and in 2 paradoxic reactions were noted. Eleven of these 12 patients had failing change in the forward bent position as well. In 1 patient only, with paradoxic reactions, did the nystagmus change toward the cooled-down side when the head was bent forward.

In 6 of these 12 patients the reactions had been normal previously except for a lack of change at forward bending. In 2 there was no caloric reaction whatever at one time, but later there were normal reactions except for the lack of change when the head was bent forward.

In 10 of the 12 patients the caloric reactions became normal later, yet still with lack of change at forward bending.

Finally, in 6 of the 48 patients the caloric reaction could not be released. Five of these had spontaneous nystagmus, and the stimulus applied, generally insufflation of air, may not have been strong enough. Subsequent tests gave normal reactions except for lack of change when the head was bent forward.

The points of time at which normal reactions, except for lack of change, were demonstrated in the latter two groups, comprising 18 patients, ranged from five weeks to fifteen months after the operation.

The results of the caloric test have been recorded in table 8.

COMMENT

The results of the different tests have been recorded in table 9.

The question of particular interest to be elucidated is whether the reversal or the varying or the absence of the fistula sign (despite the unquestionable presence of the fistula on the vestibule or the adjacent part of the horizontal canal) and the abnormal caloric reaction are due to loss of function of the horizontal canal.

TABLE 8.—*Abnormalities Observed at Caloric Tests Made After the Operation (76 Patients Tested)*

Type of Abnormality	Patients Presenting Given Abnormality
Failing change at forward bending	30
Other abnormal reactions	12
Loss of caloric reaction	6
Total	48

TABLE 9.—*Combinations of Abnormalities of Function Observed in the Different Tests*

	Failing Postrotatory Reaction from Horizontal Canal (8 Patients)	Reduced Postrotatory Reaction from Horizontal Canal (12 Patients)	Abnormal Caloric Reaction (48 Patients)	Absence of Fistula Sign (13 Patients)	Reverse or Varying Fistula Sign (12 Patients)
Failing postrotatory reaction from horizontal canal (8 patients)	..	..	6	2	3
Reduced postrotatory reaction from horizontal canal (12 patients)	..	..	9	2	5
Abnormal caloric reaction (48 patients)	6	9	..	12	6
Absence of fistula sign (13 patients)	2	2	12	..	..
Reverse or varying fistula sign (12 patients)	3	5	6	..	..

The absence of postrotatory reaction from the horizontal canal constitutes the basis for an investigation of this question.

It appears from table 9 that in 11 of 13 cases with absence of the fistula sign the horizontal canal reacted on the rotation stimulus, though the reaction was impaired in 2 cases. Thus, absence of the fistula sign was not necessarily due to loss of function of the horizontal canal. It may have been due to the fact that the pressure could not act on the membranous labyrinth through the plastic flap or to the fact that the horizontal canal was slightly damaged, since in 12 of the 13 patients with absence of the fistula sign the caloric test gave no change of the lateral nystagmus when the head was bent forward.

The conditions are similar where the reverse sign or the alternately regular and reverse fistula sign are concerned: In 9 of 12 cases the

horizontal canal reacted on the rotation stimulus, though somewhat weakly in 5 cases, and further in 1 case the caloric test gave no change of the lateral nystagmus in the forward bent position. The fact that the fistula is not situated exclusively on the horizontal canal but rather over the area of contact between its ampullar end and the vestibule most likely accounts for the reverse or mixed reverse and regular fistula sign in some cases. Similar conditions have been described by Nylén [3] for the fistulous labyrinthitis.

The fistula sign could be elicited, presumably released by pressure on the sensory epithelium, in 6 of 8 cases with absence of postrotatory reaction from the horizontal canal.

As to the abnormal caloric reaction, notably the failing change of the lateral nystagmus in the forward bent position of the head, it appears that the horizontal canal responded to rotation in 42 of 48 such cases.

This observation agrees with the results of Lund's [4] investigations to the effect that one cannot conclude from the lack of change at forward bending of the head that the horizontal canal has lost its function. The lack of change, seen in such a large number of cases, viz., 62 per cent, may be due to a slight damage of the horizontal canal not involving total loss of the function of the canal. This accords with the fact that slight disturbances of the postrotatory lateral nystagmus were observed in 9 of the 42 cases.

In 2 cases the caloric test when made the first time after the operation gave downward directed vertical nystagmus when the head was bent forward, whereas when it was made subsequently there was a change of the lateral nystagmus. The fistula sign was regular in both these cases, and the horizontal canal responded to rotation. I am here in agreement with Lund,[4] who found that one cannot draw from the development of vertical nystagmus the general conclusion that the horizontal canal has lost its function.

In 2 cases with absence of postrotatory reaction of the horizontal canal the caloric reaction was normal with change at forward bending. This goes to show that the occurrence of the change is no definite proof that the normal function of the horizontal canal is present.

As mentioned before, 15 patients presented abnormal conditions of postrotatory nystagmus released from the vertical canals, and in 7 of them slight or pronounced changes of the postrotatory lateral nystagmus were demonstrated. Furthermore, the caloric reaction was now abnormal in 10 of these 15 patients. Slight or severe damage of the horizontal

3. Nylén: A Clinical Study of the Labyrinthine Fistula Symptoms and Pseudofistula Symptoms in Otitis, Acta oto-laryng., 1923, supp. 3, pp. 1-511.

4. Lund, R.: La fonction vestibulaire dans la labyrinthite fistuleuse, Rev. de laryng. **54**:285, 1933.

canal was demonstrated by rotation tests and/or caloric tests in 12 of these 15 patients.

The results of the investigations show that in a great number of the patients (45 of 78) the function of the horizontal canal was reduced —in a small number of these (8) even completely lost—after operation for otosclerosis. The function returned, however, in several cases.

The vertical canal was affected to a far smaller extent (only in 15 of 78 patients). The damage was rarely of a permanent nature.

In short, the most pronounced disturbances were demonstrated at the site of operation, the ampulla of the horizontal canal. The disturbances decreased in the remaining part of the vestibular apparatus, without reaching the cochlear apparatus, except in 2 cases, which are the only ones in which the hearing was impaired after the operation. This shows the great importance of antibiotics for the fenestration operation.

SUMMARY

The vestibular function has been tested in 79 patients before and after operation for otosclerosis.

Twenty-seven per cent of the patients had been suffering from vertigo before the operation. This symptom was present after the operation in 64 of the 79 patients.

Spontaneous nystagmus was demonstrated in the majority of the patients after the operation, varying in both duration and direction.

The fistula sign was originally present in 57 patients, but later disappeared in 11. If the fistula is still open six months after the operation, it is likely to remain so. The fistula sign was generally regular. The direction may differ with the different methods of testing. The vascular fistula sign was a frequent occurrence, also after the area of operation had healed. This sign is, in other words, not released by changes of volume of the granulation tissue in the fistula.

In rotation and caloric tests, some patients presented signs of a lesion of the vestibular apparatus before the operation. After the operation such signs were frequent, notably signs of damage to the horizontal canal and, less frequently, to the two vertical canals.

The fistula sign may be absent despite functioning of the horizontal canal, and, reversely, the fistula sign may be elicited despite loss of function of the horizontal canal.

IV. BIOCHEMICAL CONDITIONS IN PATIENTS WITH OTOSCLEROSIS

NIELS RISKAER, M.D.

SINCE 1912, when Voss [1] suggested the possibility of a relationship between otosclerosis and disturbances of the function of the parathyroid gland, various investigations have been published with the object of demonstrating metabolic disturbances of different kinds in association with this disease.

Attention has been focused particularly on the calcium metabolism. However, there have been reports also on investigations of the inorganic phosphate, cholesterol and protein contents of the serum, as well as a few on the serum potassium, magnesium, chlorine and lactic acid, the alkali reserve, the sugar metabolism and the basal metabolism. The latter investigations comprise only fairly small materials, and no great importance seems to have been attached to them.

The results achieved by the various investigators are not comparable. A brief survey, therefore, will be given here of the most important reports, comprising studies concerning calcium, inorganic phosphates, cholesterol and protein.

SURVEY OF THE LITERATURE

Calcium.—Leicher [2] (1922 and 1923) analyzed serums from 40 patients with otosclerosis and claimed to have found subnormal calcium values in 75 per cent and, in the remaining 25 per cent, an abnormal instability of the calcium metabolism. Thus, on administering 5 to 6 Gm. of primary sodium phosphate daily for from eight to fourteen days he observed a small but distinct fall in the calcium level, whereas such a fall was not demonstrable in normal persons. Results in conformity with this observation have since been published by Behrendt and Berberich,[3] Stern [4] and Altman and Kopetzky.[5]

Lindeman,[6] on the other hand, stated in 1928 that, by analyzing serums from 25 patients with otosclerosis, he found a normal calcium level in all except 2, in whose serums it was 7.1 and 7.7 mg. per hundred cubic centimeters, respectively, without the patients otherwise present-

1. Voss, O.: Verhandl. d. deutsch. otol. Gesellsch., 1912, p. 193.
2. Leicher, H.: Ztschr. f. Hals-, Nasen- u. Ohrenh. **4**:74, 1922-1923.
3. Behrendt, H., and Berberich, J.: Ztschr. f. d. ges. exper. Med. **78**:31, 1931.
4. Stern, cited by Behrendt and Berberich.[3]
5. Altman and Kopetzky, cited by Fowler.[7]
6. Lindeman, C. F.: Norsk mag. f. lægevidensk. **89**:223, 1928.

ing any particular signs or symptoms. Fowler [7] and Nager [8] arrived at similar results a few years later by analyses of serums from 58 and 30 patients with otosclerosis, respectively. In no case did they find values which could be said for certain to lie outside the normal range of variation.

Breitmann,[9] by examination of a fairly large number of patients, found the serum calcium level normal in the majority, but he encountered some whose serum gave either abnormally high or abnormally low values.

Finally, Seiferth [10] stated that the serum calcium level is normal in some patients with otosclerosis, but in most, raised. (Among 22 patients he found hypercalcemia [calcium higher than 12 mg. per hundred cubic centimeters] in 7, slightly raised levels [11 to 12 mg.] in 7, normal levels [10 to 11 mg.] in 7 and a slightly lowered calcium level in 1. Seiferth claimed at the same time to have found increased excretion of calcium in the urine in all cases except 2 [normal value set at 180 to 200 mg. for twenty-four hour urine]).

These findings were, in Seiferth's opinion, borne out through experiments with dihydrotachysterol (A. T. 10®), which ostensibly gave favorable results in a number of cases. This observation has been supported by various other investigators, including Kobrak,[11] who, however, often combined the treatment with injections of calcium.

Inorganic Phosphate.—Behrendt and Berberich [3] made analyses of serums from a fairly large series of patients of Voss's Clinic and found normal values for inorganic phosphate in all cases. Similarly, Fowler [7] stated that the phosphate contents of the serum samples examined by him from 58 patients were normal.

In contrast with these writers, Seiferth [10] claimed to have found reduced concentration of phosphate in the serums of the majority of the 19 patients examined by him. In 7 patients Seiferth found the level to be under 3 mg. per hundred cubic centimeters, which Behrendt and Berberich and Fowler regarded as indicating pronounced hypophosphatemia; in 8 patients Seiferth found between 3 and 4 mg. per hundred cubic centimeters, which is regarded as subnormal; in 2 patients the levels were slightly raised (4.6 to 4.8 mg.), and in 2 patients they were quite normal (3.9 to 4.2 mg.). Summarizing, Seiferth stated that the majority of patients with otosclerosis have increased concentration

7. Fowler, E. P.: Calcium, Phosphorous and Cholesterol in Otosclerosis, Arch. Otolaryng. **13**:77 (Jan.) 1931.
8. Nager, F. R.: Ztschr. f. Hals-, Nasen- u. Ohrenh. **34**:717, 1933.
9. Breitmann, M.: (*a*) Arch. f. Ohren-, Nasen- u. Kehlkopfh. **135**:289, 1933; (*b*) **136**:117, 1933.
10. Seiferth, L. B.: Arch. f. Ohren-, Nasen- u. Kehlkopfh. **143**:429, 1937.
11. Kobrak, F.: Pract. oto-rhino-laryng. **1**:186, 1938.

of calcium and at the same time decreased concentration of phosphate in their blood serum, so that the formula corresponds to that seen in Recklinghausen's osteitis fibrosa.

Cholesterol.—Behrendt and Berberich,[3] through comprehensive investigations, arrived at the result that a decreased cholesterol content is a characteristic and constant finding in the blood serum of patients with otosclerosis. Breitmann,[9] on the other hand, stated that an increased amount is nearly always found, at least in elderly patients. Fowler found normal, or nearly normal, not definitely pathologic values in his series of cases.

Proteins.—Only one paper has been found dealing with the proteins in the serum of patients with otosclerosis, namely, that published by Stern,[4] who claimed to have found a relative increase of the globulin fraction.

MATERIAL OF PRESENT INVESTIGATIONS [12]

The series of patients studied, from the ear department of Sundby Hospital, comprised 51 patients among those operated on for otosclerosis in 1947; 34 were women between the ages of 24 and 65, and 17, men between the ages of 26 and 67.

The blood serum analyses comprised calcium, inorganic phosphate, phosphatase, total cholesterol, albumin and globulin.

All samples were taken from fasting patients.

METHODS OF ANALYSIS AND NORMAL VALUES

The methods of analysis used and normal values are outlined:

Calcium.—Tisdall's [13] modification of the Kramer-Tisdall method.

Maximal range of variation: ±0.2 mg. per hundred cubic centimeters.

Normal value: (9.0) 9.5 to 11 (11.5) mg. per hundred cubic centimeters.

Total Cholesterol.—Brun's method as modified by Brøchner-Mortensen and Møller.[14]

Maximal range of variation: ± 8 mg. per hundred cubic centimeters.

Normal value: In adults, most often 150 to 300 mg. per hundred cubic centimeters; in a few cases, slightly higher.

Phosphatase.—The Buchs's method.[15]

Maximal range of variation: 0.5 unit.

Normal value: in adults, 2 to 8 units.

Inorganic Phosphate.—The Gutmans' [16] method, modified.

Maximal range of variation: ± 0.4 mg. per hundred cubic centimeters.

Normal value; adults, 2 to 5 mg. per hundred cubic centimeters.

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12. These investigations were carried out in the Panel Doctors Laboratory with financial support from, and under the direction of, the municipal hospitals in Copenhagen.

13. Tisdall, F. F.: J. Biol. Chem. **56**:439, 1923.

14. Brøchner-Mortensen, K., and Møller, E.: Acta med. Scandinav. **103**:259, 1940.

15. Buch, I., and Buch, H.: Acta med. Scandinav. **101**:211, 1939.

16. Gutman, E. B., and Gutman, A. B.: J. Biol. Chem. **136**:201, 1940.

Protein.—The method of Henriques and Klausen.[17]

Maximal range of variation: total protein, 0.2 mg. per hundred cubic centimeters; globulin, 0.3 mg. per hundred cubic centimeters.

Normal value: total protein, 5.6 to 8.2 mg. per hundred cubic centimeters; globulin, 1.6 to 3.2 mg. per hundred cubic centimeters; albumin, 3.5 to 5.5 mg. per hundred cubic centimeters.

RESULTS

To give the clearest possible survey of the results, each series of analyses will be dealt with separately.

Each series of analyses was carried out on blood serum samples from all 51 patients.

Calcium (normal value, 9.0 to 11.5 mg. per hundred cubic centimeters).—The first analyses showed normal levels in 48 patients. In 3 patients the levels varied a little from the normal range, being 8.1, 12.0 and 11.9 mg., respectively. However, control analyses carried out from three weeks to three months later revealed normal levels also in these 3 patients: 10.0, 10.3, and 9.9 mg., respectively.

Inorganic Phosphate (normal value, 2 to 5 mg., per hundred cubic centimeters).—The first analyses showed normal values in 44 cases. Abnormal values were found in the remaining 7 (in 5 of these, varying only slightly from the normal range), being 7.0, 1.7, 5.2, 5.2, 1.8, 5.3 and 6.1 mg., respectively. In the first, third and fifth cases of abnormal concentration repeated analyses were made from ten days to three months later, by which normal values were demonstrated: 2.4, 4.4 and 3.3 mg., respectively.

Phosphatase (normal values for adults 18 to 55 years of age, 2 to 7 units; for patients more than 55 years of age, 3 to 8 units).—The first analyses showed normal levels in 44 patients. In 7 the result deviated from the normal range of variation—in the majority, only slightly, however: For 6 of these patients, 18 to 55 years of age, the values were 7.5, 1.0, 7.4, 1.7, 10.0, and 8.5 units; for 1 patient, aged 56, 9.4 units.

Control analyses were made for nos. 2, 5 and 6. The levels were now normal in all 3: 2.0, 4.6 and 6.0 units, respectively.

Total Cholesterol (normal value 150 to 300 mg. per hundred cubic centimeters, possibly slightly higher).—The first analyses showed normal values in 47 cases. In the remaining 4 there were deviations from the normal; in 3 of these it was quite small, the values being 342, 315, 147 and 98 mg.

Control analyses made in 2 of these cases (nos. 3 and 4) about two months later revealed normal values: 258 and 301 mg., respectively.

17. Henriques, V., and Klausen, U.: Biochem. Ztschr. **254**:414, 1932.

Protein.—The normal values per hundred cubic centimeters are:

	Total Protein	Globulin	Albumin
Men	6.3-8.1 mg.	1.6-3.2 mg.	4.1-5.5 mg.
Women	5.6-8.2 mg.		3.5-5.4 mg.

On the first analyses the total protein content was within the normal range of variation in 50 cases. One patient only (a woman aged 37) presented a slight deviation, the protein level of her serum being 8.4 mg.

The globulin content was normal in 43 cases, while minor deviations were noted in the remaining 8. In most of the latter the values were below the lower normal limit: 1.3, 1.2, 3.3, 1.3, 5.3, 1.4, 1.2 and 3.4 mg., respectively. The values for total protein were normal in all these cases.

The albumin values were normal in 39 cases. In 12 patients minor deviations were presented: 6.1, 5.8, 5.9, 5.6, 5.7 mg. in men, and 2.2, 6.3, 5.8, 5.6, 5.9 and 5.7 mg., respectively, in women. In no more than 4 patients did both albumin and globulin levels deviate from the normal —in all, only slightly. The total serum protein was, as stated, slightly increased in 1 patient only.

COMMENT

In general, it may be said that in the great majority of the cases of otosclerosis normal values were found on the first analysis for all the examined substances. In the cases presenting deviations, the latter were most often very small, and for none of the substances was any tendency in the direction of a rise or a fall of the serum concentration noted. Where control analyses could be made after demonstration of abnormal values for one of the substances, such values were no longer present, but normal levels were found in all cases.

The final result is, then, that definitely abnormal values could not be demonstrated for any of these substances in the cases of otosclerosis examined.

If this result is compared with those of previous investigations, fair agreement is seen with Lindeman's,[6] Fowler's [7] and Nager's [8] findings, whereas it is not in agreement with the results achieved by Voss's collaborators (Leicher,[2] Behrendt and Berberich [3] and Stern [4]) and Seiferth.[10] No definite explanation can be given for these differing observations, but it is worth noting that the latter writers put far stricter limits to the normal variations than has been thought possible here, a fact which, of course, cannot but influence the interpretation of the results of the analyses.

One cannot entirely leave out of account the possibility that at least the comparatively great differences may denote variations in the serum concentration in different phases, active and inactive, within the course of the otosclerosis. However, no certain observations have been made so far on which to base such a theory.

Fowler [7] attached great importance to the possibility of such variations at the early stages of otosclerosis for the early diagnosis, and consequently the prognosis and the prevention of the disease. He stated that in many cases it had proved possible to stop the progression of the otosclerotic changes by regulation of disturbances of metabolism and by prevention or termination of pregnancy. He held that hardness of hearing can be prevented if the process can be stopped before the development of the stapedial ankylosis.

In the report on the progress within the study of otosclerosis issued in 1946 by the American Otological Society [18] it was stated that Fowler had recommended systematic control of all persons descending from families in which otosclerosis occurs. Particular importance was attached to the control measures within the periods of life in which it is of the greatest significance that the development of otosclerosis be prevented or arrested. These periods are said to be the first six months of life, the ages between 10 and 20 (notably 11, 12, 13, 14 and 15) and, in women, also prior to and during pregnancy, puerperium, lactation and menopause; moreover, control is advisable in periods of particularly marked growth and periods of endocrine disturbances.

Fowler is of the opinion that, in addition to otologic examinations, the control should consist in measurements, at regular intervals, of the calcium, phosphorus, protein, folic acid and phosphatase contents of serum, as well as examination of the basal metabolic rate and absorption of minerals. During pregnancy and puerperium the intervals should not exceed two months.

SUMMARY

A brief survey is made of the reports published so far on investigations of the calcium, inorganic phosphate, cholesterol and protein fraction contents of the blood serum of patients with otosclerosis. The divergent results are pointed out.

Original investigations are reported, comprising measurements of the calcium, inorganic phosphate, phosphatase, total cholesterol, albumin and globulin in serum samples from 51 adult patients with otosclerosis. Definitely abnormal values of any of these substances could in no case be found.

It is mentioned that this result does not preclude the abnormal variations in active phases of the disease mentioned by Fowler, and his proposal that control examinations be made of descendants of patients with otosclerosis is cited.

18. A Report of Progress: Twenty Years Research in Otosclerosis, Progressive Deafness and Correlated Problems, 1926-1946, New York, American Otological Society, Inc., Central Bureau of Research, 1947.

V. CONDITIONS OF THE EXTERNAL AUDITORY MEATUS AND THE TYMPANIC MEMBRANE IN PATIENTS WITH OTOSCLEROSIS

SVEND SELSØ

IN EXAMINING patients with otosclerosis in the ear department of Sundby Hospital we have tried to find out whether conditions seen in the external auditory meatus and the tympanic membrane might be of importance in differentiating between otosclerosis and other forms of impaired hearing.

The skin of the auditory meatus has been stated to be more disposed toward atrophy with reduced production of cerumen in patients who have otosclerosis than in normal persons and patients with other forms of deafness. Furthermore, it has been stated that the dimensions of the external canal are increased and the sensitivity of the skin reduced, that the tympanic membrane is thin with a reddish translucent promontorial wall, and that the mobility of the tympanic membrane is reduced as regards both the pars tensa and the membrana flaccida.

I have examined 29 patients suffering from otosclerosis with regard to the signs and symptoms described in the foregoing paragraph. Twenty-nine persons with no disease of the ear have been used as controls.

The ages of the patients with otosclerosis ranged from 26 to 67.

The sensitivity was tested by means of a steel needle with a small piece of cotton wool, not rolled too hard, at the end. The tickling was done with a light hand. The patient, without having been instructed in advance, was asked about his (or her) sensation when the external auditory meatus and the tympanic membrane were touched.

It appears from the table that a wide external auditory meatus was found a little more often among the patients with otosclerosis than among the controls. The same was the case with atrophy of the skin.

Translucent redness seen through the tympanic membrane was found in no person within these two groups. Schwartze [1] was the first to show that atrophy with light-transmitting redness of the tympanic membrane was a characteristic finding in the patients with otosclerosis. This redness is not due primarily to hyperemia of the

1. Schwartze, H.: Handbuch der Ohrenheilkunde, Leipzig, F. C. W. Vogel, 1892, p. 915.

mucosa of the middle ear but rather to transillumination of an abundance of blood in the new-formed bony tissue in the promontorial wall. According to Schnierer [2] the translucent red color is sometimes extended over the entire tympanic membrane and sometimes limited, as patches, to the upper and lower posterior quadrants. Both the diffuse and the circumscribed redness are manifestations of the same phenomenon; but, as far as I can see, the terms "transilluminating redness" and "Schwartze's sign" are both in use today. The latter denotes, then, the circumscribed red patch posteriorly on the tympanic membrane.

Conditions of the External Auditory Meatus and the Tympanic Membrane in Patients with Otosclerosis

		29 Patients with Otosclerosis	29 Controls
External auditory meatus	Wide	7	0
	Normal	19	29
	Narrow	3	0
Skin	Atrophic	5	0
	Normal	24	29
Sensitivity	Tickling reflex	19	21
	No tickling reflex	10	8
	Cough reflex	0	0
	Pain reflex	0	0
Tympanic membrane	Translucent redness	0	0
	No transluminating redness	29	29

The cerumen production was found to be the same in patients with otosclerosis and in controls.

Wojniak [3] examined 100 patients who had otosclerosis and 100 controls. Of the latter, 70 had normal hearing, while 30 had other forms of deafness than otosclerosis, chiefly nerve deafness. Wojniak's results agree with those recorded by us in Sundby Hospital, only he stated that the lumen of the external auditory meatus generally is larger in patients with otosclerosis than in persons with normal hearing, whereas it is about the same size as that observed in patients suffering from other forms of impaired hearing.

Furthermore, Wojniak found Schwartze's sign to be present in 21 per cent of the patients with otosclerosis, but present also in 10 per cent of the patients with other forms of deafness and in 4.2 per cent of the normal controls.

Finally, Wojniak observed absence of mobility of the handle of the malleus in 47 per cent of the patients with otosclerosis, 23.3

2. Schnierer, J.: Monatschr. f. Ohrenh. **58**:965, 1924.

3. Wojniak, F.: The External Ear and Drum Membrane in Otosclerosis, Arch. Otolaryng. **44**:249 (Aug.) 1946.

per cent of the patients with other forms of deafness and 14.2 per cent of the normal controls. This examination was not undertaken in Sundby Hospital.

My associates and I have made investigations of sensitivity on patients with otosclerosis after operation and found the conditions to be almost the same as before operation.

The conclusion to be drawn from the results of the investigation must be that the external auditory meatus and the tympanic membrane present no characteristics that may contribute to differentiate otosclerosis from other forms of deafness.

ACTINOMYCOSIS INVOLVING ETHMOID AND MAXILLARY SINUSES

Report of a Case

ROBERT B. LEWY, M.D.
AND
EPHRAIM L. MANNING, M.D.
CHICAGO

WHILE actinomycosis is an unusual disease, it can hardly be considered rare. Actinomycosis of the jaws is not uncommon. Thus Axhausen [1] claimed that he saw 30 cases in an average year. In all, however, the disease is rare enough that it is not often thought of as a diagnostic possibility. This is particularly true in the field of otolaryngology, where the reports of invasion of the paranasal sinuses are exceptional. Why this situation should exist when the disease is commonest in the jaws and the cervicofacial region is a matter for conjecture and further study. Reports of actinomycetic infections involving the maxillary sinus have been rare. Voss [2] (1939) reported 1 case, as did Hersh [3] in 1945.

Matheis [4] stated that 60 per cent of all cases of actinomycosis involve the head and neck, the typical history beginning with a dental extraction. Of Dobson and Cutting's [5] 11 cases of cervicofacial actinomycosis, there had been dental extractions in 9. In 6 of these instances there had been extractions before the infection became evident, and in 3 cases extrac-

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From the Department of Otolaryngology, University of Illinois College of Medicine, and the Department of Otolaryngology, Veterans Administration Hospital, Hines, Ill.

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1. Axhausen, G.: Early Clinical Picture of Jaw Actinomycosis, Deutsche med. Wchnschr. **62**:1449-1451 (Sept. 4) 1936; Das Frühbild der Kieferaktinomykose, Arch. f. klin. Chir. **183**:21-23, 1935.

2. Voss, H. G. W.: Actinomycosis, J. Am. Dent. A. **26**:260-263 (Feb.) 1939.

3. Hersh, J. H.: Primary Infection of Maxillary Sinus by Actinomyces Necrophorus, Arch. Otolaryng. **41**:204-207 (March) 1945.

4. Matheis, F. S.: Actinomycosis of Jaws and Diseases with Similar Symptoms, Internat. J. Orthodontia **23**:1032-1044 (Oct.) 1937.

5. Dobson, L., and Cutting, W. C.: Penicillin and Sulfonamides in the Therapy of Actinomycosis: Report of Sixteen Additional Cases and in Vitro Tests of Susceptibility of Actinomyces to Penicillin and Sulfadiazine, J. A. M. A. **128**: 856-863 (July 21) 1945.

tions were accomplished after the infection started. Axhausen [1] stated that these infections are produced by pyogenic organisms. The pyogenic infection is primary, forming a submucous or perimandibular abscess which drains intraorally or externally or establishes osteomyelitis. This development prepares the ground for the actinomycetic infection. In the beginning, the actinomycosis is a secondary infection; later, the actinomycosis is the main infection, and the pyogenic infection is secondary.

The causative agent of actinomycosis is Actinomyces bovis, a pathogenic, non-acid-fast, anaerobic, gram-positive fungus. Boström in 1890 claimed that the saprophytic, aerobic, acid-fast organism found in grasses and cereals is identical with the one recovered from actinomycotic lesions. He expressed the belief that the actinomycetes penetrated into the human tissues by means of awns, beards and straws, when these were introduced into the mouth by patients chewing on a blade of grass, barley or grain. Emmons,[6] however, expressed the opinion that this was an unfortunate misconception due to Boström's mistaking a saprophyte for a pathogen. Davis [7] stated that A. bovis is a facultative anaerobe, difficult to grow and grown only at body temperature. According to Wolff and Israel,[8] A. bovis does not grow on grains and grasses at all but normally inhabits the digestive tract, particularly the mouth, where it remains as a saprophyte. Given proper conditions, e. g., lowered resistance and a portal of entry, the organism becomes pathogenic, with the production of a lesion.

There has been much discussion regarding the mode of infection and the possible relationship between farm life and actinomycosis. Sanford and Magath [9] reported 119 patients, of whom only 16 were farmers, who had actinomycosis in 1922. New and Figi [10] expressed the opinion that the disease is not contagious, as it is exceedingly difficult for one to produce it by injecting infected pus into animals. They further stated that A. bovis has never been demonstrated outside the human body and, further, that it is an anaerobic organism and no spores have been demonstrated. These organisms have been found in dental caries and tonsillar crypts of normal persons. Sanford and

6. Emmons, E. W.: Actinomyces and Actinomycosis, Puerto Rico J. Pub. Health & Trop. Med. **11**:63-76 (Sept.) 1935.

7. Davis, M. I. J.: Analysis of Forty-Six Cases of Actinomycosis with Special Reference to Its Etiology, Am. J. Surg. **52**:447-454 (June) 1941.

8. Wolff, M., and Israel, J.: Ueber Reincultur des Actinomyces und seine Uebertragbarkeit auf Thiere, Virchows Arch. f. path. Anat. **126**:11-59, 1891.

9. Sanford, A. H., and Magath, T. B.: Etiology and Laboratory Diagnosis of Actinomycosis, Minnesota Med. **5**:71-80 (Feb.) 1922.

10. New, G. B., and Figi, F. A.: Actinomycosis of Head and Neck, Surg., Gynec. & Obst. **37**:617-625 (Nov.) 1923.

Magath [9] noted in almost all their 96 cases of cervicofacial actinomycosis a history of preceding dental or tonsillar disease.

Matheis [4] stated that actinomycosis of the jaw is usually more dangerous than is that of the other bones. In the skeletal bones the infection is usually secondary to infection of the soft tissues, spread by contiguity or by way of the blood stream. In the jaw it is a primary infection spread through the root canals. The picture may be misleading, and hyperostosis of the mandible caused by actinomycetic infection of the periosteum may lead to a diagnosis of sarcoma. Matheis mentioned that, whereas in bacterial abscesses the infiltration decreases and disappears in time, in actinomycosis part of the infiltration will persist. The skin appears dark red or blue-red. There exists a normal or only slightly raised temperature. Spread of the disease into the antrum, orbit or brain may initiate meningitis or encephalitis and lead to death.

Ziskin, Shoham and Hanford [11] described the infection as beginning with a cellular reaction in the soft tissues; the consistency of the lesions varies from that of a soft, gelatinous granulation tissue to that of hard, fibrous tissue, resembling cartilage. One or more firm, reddish or purplish infiltrated nodules may be seen; this development is usually observed in acute cases or in later stages of the chronic cases. The swelling may include a hard nodule or a doughy mass, a widespread woodlike induration or a combination of all three. The lymph nodes are usually involved by centrifugal extension. The maximal swelling is usually noted at the angle of the mandible and extends into the submaxillary, parotidomasseteric regions and the side of the neck.

In cervicofacial cases, the suppurative process almost always develops outward to the skin, seldom pointing into the mouth. In the mandible the infection frequently invades the periosteum, then spreads to the bone, causing a true actinomycotic osteomyelitis. Sequestrums may form.

Actinomycosis has, as distinguishing characteristics, chronicity, multiple fistulas, exudate in which sulfur granules are found, deep-seated induration, sinus tracts with orifices which have a border of "pouting" granulation tissue, trismus (in cervicofacial cases), dysphagia and protrusion of the tongue. An actinomycetic infection should be suspected if, in spite of radical surgical excision of an abscess, a new abscess suddenly forms in the neighborhood of an old one.

The sulfur granules are small, yellow, gritty granules in the pus; microscopically these show chestnut-burr-like colonies, consisting of branched mycelial threads (hyphae), occasionally with very slightly

11. Ziskin, D. E.; Shoham, J., and Hanford, J. M.: Actinomycosis: A Report of Twenty-Six Cases, Am. J. Orthodontics (Oral Surg. Sect.) **29**:193-201 (April) 1943.

clubbed ends. Granules are not always present, however, for Berestnew [12] described an atypical form which did not produce the small, yellow, gritty granules.

In the more recent references to therapy, the sulfonamide compounds and penicillin have been mentioned frequently as being effective. The striking point, however, is that the patients usually have been treated by a number of agents. Dobson, Holman and Cutting [13] in 1941 treated 3 patients with sulfanilamide, iodides and roentgen radiation. Voss [2] treated 2 persons by drainage and roentgen irradiation. Dobson and Cutting [5] (1945) used penicillin and sulfonamide compounds. Thorson and Mueller [14] (1941) used thymol, potassium iodide and roentgen radiation.

Ziskin, Shoham and Hanford [11] (1943) gave a summary of the therapy which they used: (1) administration of drugs: potassium iodide, sodium iodide, ethyl iodide, strong iodine solution U. S. P. or a colloidal preparation of iodine, copper sulfate and sulfanilamide (iodine locally or in ointment form and potassium iodide by mouth in doses as high as 250 grains [16 Gm.] or more per day); (2) irradiation: roentgen rays, radium, ultraviolet light and alpine (violet) light (roentgen rays being the most effective); (3) and use of vaccine (autogenous); (4) supportive measures: a diet with high vitamin content, and (5) surgical procedures: complete excision in early stages or, if the lesion is extensive, incision, with the application of either 50 per cent or stick potassium hydroxide (a solution of acid, usually acetic acid, to be kept on hand to neutralize this caustic).

Hamilton and Kirkpatrick [15] (1945) reported that 2 patients had been treated successfully with penicillin (25,000 to 33,000 units every three hours); 1 patient received a total of 5,800,000 units, and the other, 5,200,000 units. These authors stated that the different strains of A. bovis vary in their susceptibility to penicillin. Of five strains examined by Garrod in 1944 and compared with the Oxford H strain of Staphylococcus aureus as a standard, two showed approximately the same degree of sensitivity as did the standard staphylococcus; a third strain was eight times as resistant; a fourth strain was four times as resistant, and a fifth strain grew sparsely and atypically in sixteen times the concentration of penicillin tolerated by the staphylococcus.

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12. Berestnew, N.: Ueber Pseudoaktinomykose, Ztschr. f. Hyg. u. Infektionskr. **29**:94-116, 1898.

13. Dobson, L.; Holman, E., and Cutting, W. C.: Sulfanilamide in Therapy of Actinomycosis, J. A. M. A. **116**:272-275 (Jan. 25) 1941.

14. Thorson, J. A., and Mueller, E. F.: Probable Actinomycosis of Orbit, J. Iowa M. Soc. **31**:70-72 (Feb.) 1941.

15. Hamilton, A. J. C., and Kirkpatrick, H. J. R.: Actinomycosis Successfully Treated with Penicillin: Report of Two Cases, Brit. M. J. **2**:728 (Nov. 24) 1945.

An outstanding pathologic characteristic of actinomycosis is the formation of fibrous tissue, the amount and maturity of which varies with the balance of such factors as the age and site of the lesion, the resistance of the patient's tissues and the virulence of the infecting organism. The amount of fibrous and granulation tissue and its age affect the vascularity of the lesion and the flow of blood through it, and consequently the permeation of the lesion by penicillin in the blood and

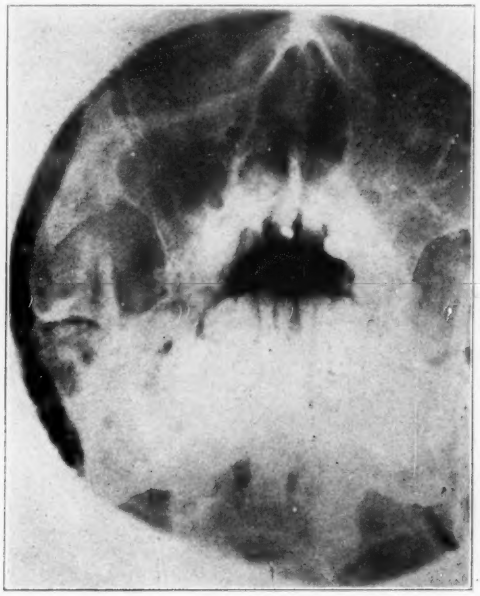

Fig. 1.—The roentgenogram shows clouding of the right maxillary sinus.

the concentration of the drug attained in various parts of the lesion. Further, actinomycosis may show a considerable degree of latency, and relapses may occur a long time after apparent cure.

REPORT OF A CASE

W. D., a 58 year old steel finisher, admitted to the Veterans Administration Hospital at Hines, Ill., on Jan. 2, 1947, gave a history of having had "flu" two weeks prior to admission and of having had a tooth extracted on Dec. 30, 1946. The extraction had been followed on the next day by swelling and pain in the right side of his jaw and face and chills and fever. Physical examination on admission revealed that he was dyspneic and perspiring profusely, appeared seriously ill and had a temperature of 103 F. He had a diffuse, tender swelling of the right side

of his face and neck, including his eyelids and the lower portion of the scalp. He had an icteric coloration of the sclera and skin. His tongue and palate were swollen, and the view of the pharynx was obstructed. The right side of the neck was swollen, hard and tender. The diagnostic impression was of an acute extensive cellulitis of the right side of the face and neck.

The patient was treated initially with hot compresses and large doses of penicillin, and he was placed in an oxygen tent. He appeared to have an adequate airway. For about two months, the patient continued to have a septic temperature, which gradually subsided to normal.

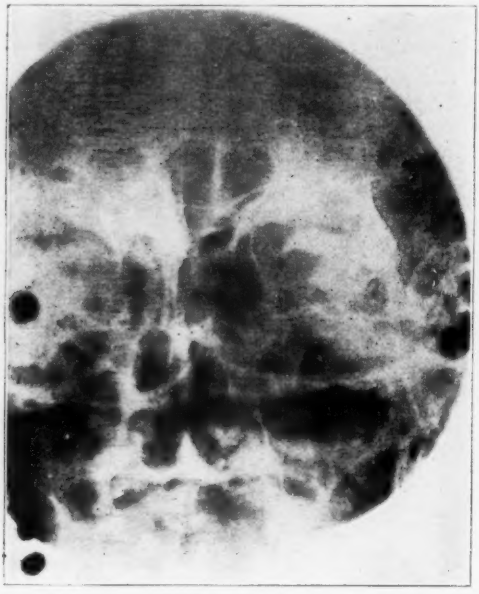

Fig. 2.—The roentgenogram shows clouding of the right ethmoid sinus.

Six days after his admission, abscesses in the right cheek and suprapalpebral and infrapalpebral abscesses were opened, and about 2 cups of purulent material was obtained. Twenty-six days after admission, an abscess under the scalp in the right parietofrontal area was incised and drained. At this time a roentgenogram of the paranasal sinuses showed distinctly decreased transparency in the region of the right maxilla (fig. 1) and a defect in the infraorbital margin, changes suggesting destruction of bone. The right frontal and right ethmoid areas showed a decrease in transparency (fig. 2).

Twenty-six days after admission, the patient was referred to the department of otolaryngology, and irrigation of the right maxillary sinus was performed. Profuse, purulent material was returned, and this patient was transferred to the otolaryngologic service.

Frequent irrigations of the right antrum and displacement treatment of the sinuses were instituted, with little change in the patient's condition. Hot compresses to the lids were applied continuously. Roentgenograms of the sinuses repeated two weeks after the first set showed essentially the same conditions as those revealed in the original films.

A roentgenogram taken five days after his admission showed a small sequestration in the right mandible.

On February 24, about eight weeks after admission, a right Caldwell-Luc operation and a transantral ethmoidectomy, with removal of osteomyelitic maxillary bone, were performed. A defect was found in the roof of the antrum.

After these procedures, the infection of the antrum and in the anterior facial region subsided, but the fistulas in the lids continued to drain copious amounts of pus, and marked edema of the lids and chemosis of the conjunctiva remained.

Fig. 3.—(*A*) The patient is shown before successful treatment. Chemosis of the eyelid and two orbital fistulas may be observed. (*B*) The patient is apparently completely cured. There is moderate discoloration of the skin around the orbit as the result of roentgen therapy.

The mouths of the draining sinuses showed heaped-up granulation tissue. Irrigation of the lower fistula produced drainage from the upper one, showing a connection between the two. Iodized oil U. S. P. was instilled through the lower fistula, and a roentgenogram showed the sinus tract extending from the region of the anterior surface of the malar bone to a cavity in the lateral portion of the roof of the orbit and entering the sinus tract in the upper lid.

During the first twenty-four days the patient received 50,000 units of penicillin every three hours, intramuscularly, for a total of 9,600,000 units. At various other times during his treatment he received 7,300,000 more units of the usual type of penicillin and 3,300,000 units of penicillin in oil and white wax U. S. P. In all, he received 20,200,000 units of penicillin intramuscularly, as well as 7,000,000 units orally. For about four weeks he received sulfadiazine with the penicillin.

Cultures taken nine days after the onset of the infection revealed hemolytic and nonhemolytic Staphylococcus albus. Five weeks after the onset of the infection, hemolytic Staph. aureus was recovered. Two months later an anaerobic culture showed nonhemolytic diphtheroids, and, about nine weeks after the infection began, another anaerobic culture revealed A. bovis.

Under the combined penicillin-sulfonamide therapy, to which oral administration of thymol, irrigations of the sinus tract with 10 per cent thymol and drainage were added, the inflammation gradually subsided about four months after its onset.

COMMENT

Retrospection indicates that the correct diagnosis might have been arrived at earlier than it was. The delay was due largely to the rarity of the disease in the antrum and the ethmoid sinus. Certainly in any chronic infection of the face, jaw or antrum which displays multiple abscesses and sinuses and which resists treatment repeated anaerobic cultures should be made in order that an accurate diagnosis may be established.

So many modes of treatment were tried in this case that it is difficult to decide which, if any, was effective. The first wave of improvement followed the surgical removal of the necrotic maxillary and ethmoid bones. However, shortly after this, improvement was at a virtual standstill, and it was at this plateau that the administration of thymol was instituted. It was given in rather small dosage, and there is left the question of the effectiveness of thymol in this infection. Its use had been preceded by roentgen therapy, which may have been having a long term beneficial effect.

In the light of this case and the previous experience of others, adequate treatment would seem to be in the form of a combined attack. Surgically, all abscesses should be opened and drained, and all necrotic bone should be removed. Medically, a combination of penicillin, sulfonamide drugs and thymol is desirable. Roentgen therapy should be used conjointly. The most important determining factor is early diagnosis.

SUMMARY

1. The record, with comment, is presented of a case of actinomycosis of the right maxillary and the right ethmoid sinus, with some cutaneous and orbital spread.

2. The problem of modern diagnosis and treatment of the condition is considered.

25 East Washington Street (2).

INTERPRETATION OF HEARING TESTS

STACY R. GUILD, Ph.D.
BALTIMORE

THE DETAILED reviews and discussions of evidence necessary to evaluate critically the reliability of the interpretations that have been made of hearing tests would take more time than is available today. This presentation will therefore be limited to general considerations of certain aspects of the topic.

NONMEDICAL INTERPRETATIONS OF HEARING TESTS

To most members of the present audience, the title of this paper calls to mind medical problems. Before proceeding to the discussion of the medical aspects of the topic, however, I wish to remind you that hearing tests are interpreted and used in many ways other than diagnostic. For instance, since time immemorial every employer has noticed, consciously or subconsciously, the ability of applicants to hear and has interpreted these observations in terms of jobs. At the present time, the military services of our own and of other countries, without direct concern about the causes of poor hearing, have rules with respect to hearing acuity as part of their requirements for enlistment and for various types of duty assignments. Likewise, school administrators interpret hearing tests in terms of educational assignments to special classes or schools.

Modern telephonic and radio communication systems are all based on hearing tests interpreted in terms of electrical circuits and apparatus. To transmit electrically, without distortion, the entire range of frequencies of sound waves that man can perceive is an exceedingly difficult problem from the standpoint of apparatus; therefore acoustical physicists and engineers have devoted much time and energy to the study of how well the voice can be understood when its sounds are imperfectly transmitted and to the determination of what types of imperfections are permissible. Some of the results of these nonmedical interpretations of hearing tests are of great practical importance in the everyday life of tens of millions of persons; for instance, our telephone bills would

From the Otological Research Laboratory, the Johns Hopkins University School of Medicine.

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be many times larger than they now are if for the understanding of speech it were necessary to have the receiver emit faithfully all the sounds that enter the distant mouth piece. Incidentally, some of the imperfections that have been found to be permissible are utilized deliberately in some forms of communication apparatus to reduce or to eliminate the transmission to the ear of extraneous sounds or noises which otherwise would interfere seriously with the understanding of the transmitted speech sounds.

Phonographs and talking movies are other examples of large scale applications of nonmedical interpretations of hearing tests. Architectural acoustics is also based on hearing tests: unfortunately the builders of auditoriums often neglect the knowledge of specialists in this field.

The use of tests of hearing in the manufacture of hearing aids, as well as in their retail sale, is perhaps better known to the members of this audience than are the other examples of nonmedical interpretations of hearing tests that have been mentioned. The interpretations made of hearing tests in the designing and in the fitting of hearing aids, even by noncommercial persons, are basically different from those desired in medical diagnosis, and the topic, although of interest to many otologists, is mentioned now merely as another example of the numerous interpretations that are and can be made of tests of hearing.

MEDICAL INTERPRETATIONS OF HEARING TESTS

Medical men wish to interpret hearing tests in terms of physiology, of pathology and of therapy, not in terms of jobs, of apparatus or of school assignments. Unless they themselves are conducting investigations on deafness, otologists, when examining patients who are hard of hearing, wish mostly to determine why the deafness exists and to decide what can be done to alleviate the impairment present or to prevent the development of further impairment.

Every otologist is faced daily with the problem of how to interpret the tests he has made of a patient's ability to hear and also with the problem of whether additional tests would add information of value in the establishment of a diagnosis or in the decision as to what form of treatment, if any, should be used. Most otologists feel a bit bewildered, to say the least, by the multiplicity of new hearing tests that have been devised and described during the past decade or so. Each test has been warmly advocated, often by several authors, for one purpose or another. Faced by this situation, the conscientious otologist often wonders whether, in fairness to his patients, he should not make provision for the administration of some or of all of these new, and usually elaborate and time-consuming, tests.

The problem is not a new one, even though the tests themselves may be. Over half a century ago, in 1896, Bezold [1] in one of his numerous papers about hearing tests wrote the following:

> In the course of recent years so many and in part time-robbing [*zeitraubende* is the word Bezold actually used] testing methods have been devised and carried out by various authors, that a purposeful, clear-headed, limitation of diagnostic procedures to the necessary and to the most certain and most rapid must be regarded today as indeed one of the most difficult tasks for otologists.[2]

Many, but not all, of the tests of Bezold's generation have become of interest only to historians, but otologists still are faced with difficult choices between what may be termed "ideal" examinations of patients and what is practical.

At least ten to twelve hours of time per patient would be needed to administer all the hearing tests now regarded by one or another investigator as of interest and value. The apparatus to make possible the administration of these tests would cost a minimum of several thousands of dollars. This figure does not include the cost of the special rooms needed for satisfactory use of the testing apparatus, nor does it include salaries of specially trained technicians to use the apparatus or payments to skilled electronics engineers to keep the various pieces of apparatus in proper operating condition.

The pure tone audiometer is the only apparatus for testing hearing, new since Bezold's time, that has been widely accepted in clinical otology. The diagnostic importance of a knowledge of air conduction thresholds for a series of tones, from low to high pitched, has long been recognized. For determining such thresholds the pure tone audiometer is a time saver, compared to other methods. Probably this is the reason that the audiometer, a by-product of hearing tests in nonmedical fields and itself regarded fairly recently as an elaborate test instrument, has been widely accepted and used by otologists. The other test procedures commonly used (the Weber, Schwabach and Rinne tests, performed with a 435 or a 512 double vibration steel fork, the watch tick, the whispered and the spoken voice) date well back into the nineteenth century.

By means of these older tests alone, made with suitable masking of the opposite ear when indicated, the hearing impairment which a patient has can quickly be classified as to type and usually as to subtype. Beyond this point, for purposes of diagnosis and therapy, the history and the physical examination yield the important clues. The cause of the impairment certainly cannot be determined by hearing tests considered without reference to the history and the physical

1. Bezold, F.: Ueber den gegenwärtigen Stand der Hörprüfungen, Ztschr. f. Ohrenh. **29**:1, 1896.

2. Translated by the author.

examination. For instance, no battery of hearing tests can distinguish between impaired hearing caused by otosclerosis and that caused by impacted cerumen, between impaired hearing due to advanced age and that in a 10 year old child afflicted with the Manasse type of hereditary progressive nerve deafness or between the possible causes of total deafness. The otologist therefore uses hearing tests primarily to supplement the data derived from history and physical examination and to confirm impressions already gained as to which part or parts of the organ of hearing are functioning poorly. He knows that by a series of elaborate, time-consuming tests several aspects of the patient's hearing disabilities, including thresholds, can be measured with more precision than by the tests he uses. He doubts, however, that this additional information will give reason to change the basic diagnosis that can be made from a carefully taken history plus a good physical examination and simple, quickly made tests. Furthermore, the otologist doubts that the elaborate tests will add information apt to change the decision as to what treatment, if any, is indicated.

The doubts of clinical otologists with respect to the preceding points are well founded. Only a few of the lesions that affect hearing can be seen and inspected during life; the correlations of these lesions with hearing losses are well established. Most of the lesions that cause impaired hearing can be studied only by histologic examination after death. By this method important correlations have been made with hearing losses known to have been present during life, but the number of cases that have been thus studied is too small to warrant conclusions as to the effect on hearing of small differences in lesions of the same general type. In other words, as yet only large differences in hearing can be correlated with differences in the lesions responsible for the impaired function.

The basic questions a clinician might well apply to each proposed hearing test are:

1. What may I learn, that I do not already know, by making this additional test?

2. How good is the evidence that the interpretations made of data obtained by this test are correct?

3. If correct, what value do the interpretations made of the data from this test have in the care of patients?

The answers to these questions must always take into account the present state of knowledge not only of correlations between hearing losses and lesions but also of the physiology of the organ of hearing, which of course includes portions of the central nervous system as well as

the ear. The most important physiologic facts, all well known for years, are (1) that sound waves are transmitted to the organ of Corti according to the laws of that branch of physics known as acoustics, (2) that stimulation of the hair cells of the organ of Corti by sound waves causes the form of biologic activity known as nerve impulses to occur in fibers of the cochlear nerve and (3) that these nerve impulses are in some manner relayed via the chain of neurons of the auditory pathways to the auditory cortex of the cerebrum. Nothing is known of how the nerve impulses that reach the auditory cortex call forth perceptions of sound, meaningful or otherwise. Furthermore, the modus operandi of the hair cells of the organ of Corti is unknown, despite the numerous papers that have been published on the topic. The well documented fact, however, that the fibers of the cochlear nerve terminate about the hair cells of the organ of Corti does make the location of the transition from physical sound waves to biologic activity completely unquestioned. This fact is, indeed, the basis for the division of impaired hearing into the two broad groups of conductive deafness and nerve deafness. Anything which interferes with the normal transmission of sound waves to the organ of Corti gives rise to a conductive type of deafness; anything which decreases or prevents the normal reactions of the hair cells to stimulation by sound waves or which interferes with or prevents the normal reactions of the nerve fibers of the pathways from the organ of Corti to the cerebral cortex gives rise to what is termed nerve deafness. Both types of impairment may of course be present simultaneously and give rise to a so-called combined deafness.

Additional important facts about the organ of hearing, perhaps not so widely known as those previously mentioned but nevertheless so well established that they should always be kept in mind in choosing and in interpreting diagnostic tests, are: (*a*) each organ of Corti sends nerve impulses not only to the opposite side of the brain, as formerly believed, but also to the same side, i. e., each ear has bilateral cortical representation, not merely contralateral[3]; (*b*) each part of the length of an organ of Corti sends nerve impulses to discrete parts of the cortex rather than diffusely to all parts of the auditory area, as was formerly believed[3b, c]; (*c*) high-pitched tones are mediated

3. (*a*) Bunch, C. C.: Auditory Acuity After Removal of the Entire Right Cerebral Hemisphere, J. A. M. A. **90**:2102 (June 30) 1928. (*b*) Woolsey, C. N., and Walzl, E. M.: Topical Projection of Nerve Fibers from Local Regions of the Cochlea to the Cerebral Cortex of the Cat, Bull. Johns Hopkins Hosp. **71**:315 (Dec.) 1942. (*c*) Walzl, E. M.: Representation of the Cochlea in the Cerebral Cortex, Laryngoscope **57**:778 (Dec.) 1947.

by the organ of Corti of the basal turn of the cochlea [4], and (*d*) interference with the physical transmission of sound waves to the organ of Corti by conductive lesions often causes more impairment of hearing for high tones than for low tones.[5]

The last statement is so at variance with classic concepts of the significance of impaired hearing for high tones that many otologists still do not accept and utilize the idea in their daily work. Proof of the statement, however, is so simple that every otologist can easily make the critical experiment himself. It is as follows: Determine the air conduction thresholds of an ear with good hearing and compare them with the thresholds of the same ear obtained when the external auditory canal is completely occluded by an obturator. The firmer the obturator, the greater is the impairment for high tones; certainly an obturator by its presence cannot cause a true nerve deafness.

Otologists and others who are interested in the careful selection and fitting of hearing aids use some rather time-consuming quantitative tests that are not of value in diagnostic work but are important in the securing of satisfactory utilization of an aid. As more and more otologists become actively interested in hearing rehabilitation, it is probable that diagnostic significance will become established for some of the functional differences that are revealed by tests of abilities of deaf persons to comprehend amplified speech. At the present time, however, histopathologic evidence does not exist to support any of the hypothetic interpretations that have been proposed as explanations of functional differences observed in the fitting of hearing aids on persons with otherwise similar degrees and types of deafness.

The statements made in this paper may give the impression that I am opposed to the use of any but the more simple hearing tests. Such an impression would be erroneous. My attitude, rather, may be summarized as follows:

The information obtained from the elaborate tests, or batteries of tests, is primarily of research interest, and until the significance of the data obtainable by these tests has been evaluated in terms of lesions that otherwise would be overlooked or in terms of therapy that otherwise would not seem indicated, clinical otologists should not be urged to use them or made to feel they are out-of-date if they do not. In other words, it is time for a clear distinction to be

4. Habermann, J.: Beitrag zur Lehre von der professionellen Schwerhörigkeit, Arch. f. Ohrenh. **69**:107, 1906. Crowe, S. J.; Guild, S. R., and Polvogt, L. M.: Observations on the Pathology of High-Tone Deafness, Bull. Johns Hopkins Hosp. **54**:315 (May) 1934.

5. Crowe, S. J., and Guild, S. R.: Impaired Hearing for High Tones, Acta oto-laryng. **26**:138, 1938. Proetz, A. W.: Hearing Acuity Varying with the Position of the Head, Ann. Otol., Rhin. & Laryng. **57**:241 (March) 1948.

made between tests for research purposes and those for clinical purposes. Nothing is gained clinically by the making of hearing tests that cannot be interpreted with reasonable certainty in terms of causative lesions. All too often a diagnosis, so-called, amounts to nothing but a statement of the kinds of hearing defects found by the tests made. Such a statement, no matter how elaborate the battery of tests used or how detailed the report of the data obtained, is merely a description, and not an interpretation, of hearing tests and has no medical usefulness whatsoever.

On the whole, it seems that the reluctance of most clinical otologists to spend time making refined, precise measurements by means of the elaborate methods devised for the testing of various aspects of the hearing function is justified by the paucity of interpretations of proved medical value. The situation constitutes a challenge to investigators.

ABSTRACT OF DISCUSSION

Dr. Lawrence R. Boies, Minneapolis: This paper is valuable because it emphasizes a return to fundamentals. When I began the study of otology, the audiometer was coming into general use in institutions. As its use developed in the private practice of otology, some of us began to rely on it as an instrument for a more or less complete hearing test. We were not unlike the physician who examines the chest largely by roentgenology and neglects the art of careful physical study and to some extent history taking.

The audiometer has undergone marked improvements in the past twenty years, but it still remains, as Dr. Guild has inferred, an instrument for quickly and reliably measuring air conduction thresholds. Many otologists are hesitant to accept audiometric interpretation of bone conduction values and have more confidence in the time-honored tests with steel forks. Some of us who had been lulled into seeming security by the latest improvements in audiometric testing were stimulated to critical inquiry by the developments in regard to otosclerosis during the past ten years.

I think it may be safely said that among those who are now doing fenestration surgery the tests which would be discarded last in the critical evaluation of the patient would be those performed with tuning forks. Most surgeons who perform fenestrations apparently place the greatest reliance on the Rinne test performed with the 512, 1024 and 2048 forks. It is logical that the ability to understand speech should be the best criterion of one's practical ability to hear, and some tests have been developed and others are being developed and simplified which may become a desirable substitute for the tests with tuning forks. At the present time, however, it is my belief that we should continue to utilize the fundamental tests and teach them to our men in training.

Dr. Guild has had a background in certain fundamental phases of otologic research probably unsurpassed by anyone in the Americas and possibly elsewhere. This gives authority to his opinions, and for emphasis I would repeat his statement to the effect that "the information obtained from elaborate tests, or batteries of tests, is primarily of research interest, and until the significance of the data obtained by these tests has been evaluated in terms of lesions that otherwise would

be overlooked, or in terms of therapy that otherwise would not seem indicated, clinical otologists should not be urged to use them or made to feel that they are out-of-date if they do not."

Dr. John R. Simpson, Pittsburgh: I wonder if some of you are not having the same experience that we are having in instructing young men in otology. They do not seem to be interested in learning the use of tuning forks and too often refer the taking of an audiogram to a technician. I wonder if they are not missing something by such practice. I recall that some years ago Dr. John B. Rae, of New York, at a session of the Triological Society, gave a demonstration of the proper use of tuning forks. It was one of the most instructive talks that I ever listened to in any society meeting.

Those of us who have been brought up on tuning forks find their continued use helpful, and they serve as a check and supplement the information gained from the use of the audiometer.

Dr. Stacy R. Guild: I wish to thank both discussers for their kind remarks. I really expected a few brickbats. I am sorry Dr. Furstenberg could not be present to participate in the discussion. Dr. Simpson's point is most excellent, and I agree that stress should be placed on teaching the fundamentals of the testing of hearing. As it is, all too often a secretary or a nurse or a technician puts on paper some lines which the physician responsible for the care of the patient accepts as a reliable hearing test.

The paper today is the outgrowth of numerous conversations with visitors to the laboratory. Most of the otologists, both from this country and from abroad, have wanted to talk about new hearing tests and what this, that or the other one means. When Dr. Woodward, the chairman, asked me to speak here, I thought more phases of the topic could be presented in fifteen minutes than has been possible. The presentation today, therefore, must be regarded as chapter I or as a general consideration of the topic, to be followed later, perhaps, by detailed discussions and evidence on the various subtopics.

Abstracts from Current Literature

Ear

THE HEARING ACUITY, TINNITUS AND VERTIGO IN ESSENTIAL HYPERTENSION. LEIGHTON F. JOHNSON and BERNARD ZONDERMAN, Laryngoscope **58**:374 (May) 1948.

Seventy-six consecutive cases of severe hypertensive vascular disease were studied to determine the relation to loss of hearing, tinnitus and vertigo. Complete examinations of the ears, nose and throat, including the taking of audiograms, were made. Tinnitus and vertigo were found to be very common, occurring in 30 and 46 per cent, respectively, and were frequently relieved by splanchnicectomy. There was little (10 per cent) subjective deafness, but a frequent dip of the audiometric curve at 2,896 and 4,096 double vibrations.

HITSCHLER, Philadelphia.

OBSERVATIONS UPON THE LOUDNESS RECRUITMENT PHENOMENON, WITH ESPECIAL REFERENCE TO THE DIFFERENTIAL DIAGNOSIS OF DISORDERS OF THE INTERNAL EAR AND VIII NERVE. M. R. DIX, C. S. HALLPIKE AND J. D. HOOD, Proc. Roy. Soc. Med. **41**:516 (Aug.) 1948.

From an investigation of the loudness recruitment phenomenon, the authors have derived conclusions that are proving to be major and brilliant contributions to otology. Using loudness balance tests, they studied 30 cases of unilateral deafness due to Ménière's disease and 20 cases of degeneration of the eighth nerve due to neurofibroma or other lesions of the cerebellopontile angle, as demonstrated at operation or autopsy.

Results indicated that the loudness recruitment phenomenon was present and complete in all 30 cases of Ménière's disease. Microscopic studies of the organs of Corti in cases of this disease generally revealed pathologic changes. Clinical deafness in many patients with Ménière's disease suggests that residual microscopic changes in Corti's organ exist but are obscured by the limitations of histologic technics. The nerve fibers and the cells of the spiral ganglions in these cases are normal.

Loudness recruitment was found to be absent in 14 of the 20 cases of degeneration of the eighth nerve. In the remaining 6 cases it was present, but incomplete. Microscopic studies of the organs of Corti in cases of degeneration of the eighth nerve generally showed normal structure. However, in these cases there was extensive pathologic change in the nerve fibers and in cells of the spiral ganglions.

Loudness recruitment was thus shown to be characteristically present in a disorder of the organ of Corti and to be characteristically absent in a disorder of the cochlear nerve fibers. These findings controvert present views on the neurologic mechanism of recruitment. The authors advance a new hypothesis based on their observations and other recent experimental work. They suggest that the loudness recruitment phenomenon may be very useful in distinguishing degeneration of the eighth nerve from disease of the peripheral end organ.

SATALOFF, Philadelphia.

Pharynx

TREATMENT OF TUBERCULOUS PHARYNGOLARYNGITIS WITH STREPTOMYCIN. JOSE A. BERTELLI, Rev. argent. de oto-rino-laringo. **17**:83 (March-April) 1948.

Bertelli reports on a group of 16 patients with pulmonary tuberculosis in whom positive signs of involvement of the larynx or the pharynx appeared as complications of the pulmonary tract. The extent of involvement of the larynx varied from mild ulceration of the vocal cords to extensive lesions, not only of the cords and the arytenoid cartilages but also of the epiglottis. These patients received streptomycin therapy in large doses and for a long period. Some patients received as much as 125 Gm. during the course of treatment. The cardinal symptoms of dysphagia, dysphonia and neuralgic pains were all affected favorably by the use of streptomycin. Nine patients who complained of dysphagia were cured; 8 of the 12 patients with dysphonia showed complete disappearance of this complaint, with definite improvement in 3 others. Laryngoscopic examination of these 12 patients showed complete cure in 6, almost complete cure in 2, pronounced improvement of the more extensive lesions in 3 and improvement in some of the discrete lesions in 5.

The untoward reactions are classified as of three types: (1) what Bertelli calls histamine reactions (headaches in 2 cases and nausea in 3); (2) neurologic disturbances (vertigo and nausea in 4 cases, hypoacusia in 2 cases, insomnia in 2 cases and ocular pain in 1 case), and (3) sensitization reaction (cutaneous eruptions in 1 case and fever in 1 case).

In his conclusions, Bertelli states: 1. Streptomycin is the most efficacious medication that we have at present for the treatment of laryngeal tuberculosis. 2. It is efficacious in treatment of all pathologic forms in this region. 3. The exudative forms are the most sensitive to treatment. 4. Dysphagia yields to treatment with the greatest promptitude. 5. A rapid alleviation of the painful symptoms benefits the general state of the patient, and a cure of these lesions eliminates an important obstacle to the better treatment of pulmonary lesions.

PERSKY, Philadelphia.

Nose

TURBINATE TREATMENT IN VASOMOTOR RHINITIS. JOHN R. RICHARDSON, Laryngoscope **58**:834 (Aug.) 1948.

The condition of vasomotor rhinitis is aggravated by the improper use of shrinking solutions. A careful history and study should be made and treatment carried out in conjunction with an allergist. When all forms of treatment apparently fail, and especially when no specific allergen is found, electrocoagulation and exfraction of the inferior turbinate body should be used. These methods give better results, in the author's hands, than injection with sclerosing fluids.

After local anesthetization, twin needles are inserted submucosally from the anterior to the posterior third of the inferior turbinate body: The current is applied, the needles are withdrawn, the current again applied, and so on, so that several areas of scar tissue are formed. Richardson treats the turbinate body first; four weeks later the patient returns to have the other side treated. The results are usually permanent.

Hitschler, Philadelphia.

THE NEW TECHNIQUE FOR LOCAL ANESTHESIA IN SINUS SURGERY. WILLIAM LAWRENCE GATEWOOD AND C. AUGUSTUS DE VERE, Laryngoscope **58**:848 (Aug.) 1948.

The authors discuss briefly the advantages of local anesthesia over that of general anesthesia, and treat separately each nerve involved in operations on the sinuses. Included are illustrations and explanations showing how and where the injection is made, the amount and strength of anesthetic solution and structures anesthetized by the nerve in question. The article is clear and concise and is good for reference before sinus surgery.

HITSCHLER, Philadelphia.

THE ABUSED DIAGNOSIS OF SINUSITIS. C. CALVIN FOX, Pennsylvania M. J. **52**:136 (Nov.) 1948.

The author points out, first, that the diagnosis of sinusitis is, too often, erroneously made by both the general practitioner and the otolaryngologist; second, that many of the symptoms and some of the physical findings in cases of sinus infections are also often present in cases in which the sinuses are free from infection. To cases of this kind the term sinusitis or pseudosinusitis could well be applied. Only by a careful history, consideration of the symptoms and intranasal and special physical examinations by physicians who are thoroughly trained and experienced in evaluating them, can a proper differential diagnosis be made.

In order to reduce the too casual use of the term sinusitis, it should be kept in mind that patients who have frequent or persistent headache, facial pain, excessive nasal or postnasal discharge or nasal obstruction, in various combinations, are sufficiently distressed, and many present a diagnostic problem difficult enough to justify the combined skills of the internist, the roentgenologist and the otolaryngologist.

LANDIS, Reading, Pa.

Miscellaneous

FUNDAMENTALS IN THE TREATMENT OF COMMUNICATIVE DISORDERS CAUSED BY HEARING DISABILITY: II. MIRIAM D. PAULS and WILLIAM G. HARDY, J. Speech & Hearing Dis. **13**:97 (June) 1948.

The treatment of communicative disorders caused by hearing disability involves the closest coordination of medical and nonmedical services. Complete diagnostic evaluation includes an otologic examination, a full series of hearing tests, psychoacoustic and psychosocial examination and a thorough case history. Special attention is paid to the patient's communicative habits, his attitudes and behavior in typical communicative situations.

The terms deaf, hard of hearing, etc. are not physiologically sound. It is convenient to refer to these, instead, as marginal, moderate and profound hearing loss. Out of almost 5,000 service personnel and veterans known to the authors, fewer than a dozen were so affected that they could not profit from the use of a hearing aid and retraining with amplified sound. The group with mild loss of hearing has the greatest difficulty in adjusting to the communicative problems.

Several guide lines must be followed in working with persons with hearing disabilities. First, the doubts, confusions and questions of the handicapped person must be faced squarely. Second, the person must have ample opportunity to learn to listen to amplified sound, center his attention in ambient noise, extend the limits

of his tolerance for loud sound and to utilize every possible auditory cue. Third, once the choice of hearing aid has been determined, the person must learn to use it in a wide variety of situations. Fourth, he must understand the role of speech reading. Fifth, there should be sufficient instruction in the fundamentals of articulation and voice production to insure his retention of adequate habits. Sixth, problems of psychosocioeconomic adjustment should be discussed freely.

PALMER, Wichita, Kan.

DIAGNOSIS AND PROGNOSIS IN CLEFT PALATE SPEECH. CLAUDE E. KANTNER, J. Speech & Hearing Disorders **13**:211 (Sept.) 1948.

Nasality in speech at present is still a subjective phenomenon. The degree of nasality does not seem to be directly related to the amount of air escaping through the nose or the degree of opening of the soft palate. Nasality in cases of cleft palate cannot be dealt with intelligently on the assumption that it is simply a matter of repairing the soft palate and then learning to use it. Devices for showing nasality may be very valuable as means of teaching but are not valuable or reliable as detectors of nasality. It is necessary to observe the speech patterns, the speech organs and the case history in order to predict a proper series of technics. An outline of the proper procedure in diagnosis is presented. The goal for every person with cleft palate should be to avail himself of the best possible speech training commensurate with his needs, physical limitations, mental ability and potential contribution to society. The author believes that medicine and surgery are both closer to this goal than are speech clinicians.

PALMER, Wichita, Kan.

TECHNIQUES IN THE MANAGEMENT OF APHASICS. VIVIAN M. SHEEHAN, J. Speech & Hearing Disorders **13**:241 (Sept.) 1948.

Sheehan reports a case, together with a general description of clinical management of aphasia, and reaches the following conclusions:

1. The patient with aphasia can learn without the use of fatiguing drill.
2. He must work toward specific and well defined goals.
3. He must realize he cannot reach perfection or normal speech.
4. The clinician must differentiate between the severity of the aphasia and that of the handicap.
5. Definite phrases should be taught, which should be used automatically.
6. Every effort should be made to reduce and simplify the task. The person with aphasia should not be handled in any way which promotes competition between different patients, nor should any clinician ever put the responsibility for recovery on the person with aphasia.

PALMER, Wichita, Kan.

ANTICIPATORY SPEECH RESPONSES IN CHILDREN WITH ARTICULATORY DEFECTS. MARY ELLEN HULL, J. Speech & Hearing Disorders **13**:268 (Sept.) 1948.

Thirty-two public school children, ranging in age from 5 to 12, with articulatory defects were compared with 14 normal controls of the same age and general intelligence. A series of tests of repetition of vowels in nonsense syllables and words were given individually to each child in an effort to describe a phenomenon observed at the Institute of Logopedics known as the anticipatory response.

1. In children with articulatory defects, production of each syllable was altered to a much greater extent when repeated in an anticipatory manner than when there was a delay between the stimulus sound and the speech response. 2. The anticipatory speech response is not limited to children with articulatory defects. 3. One child who was nervous, distractible and of below average intelligence made such responses. 4. Any child with an articulatory defect who had anticipatory reactions of sound could be taught to inhibit these reactions.

The anticipatory speech response is defined as that type of response in which the child has an overrapid sound reaction in speech to the stimulus of a nonsense syllable by the examiner, and the child's reaction apparently occurs without conscious study of production. In the normal child and in the child with articulatory defect the usual response is produced with a considerable delay between the utterance of the syllable by the examiner and the response by the child.

PALMER, Wichita, Kans.

THE CELLULAR AND HUMORAL FACTORS INFLUENCING CONSTITUTIONAL RESISTANCE AND THE DEVELOPMENT AND CONTROL OF LOCAL LESIONS. CHARLES A. DOAN, Laryngoscope **58**:879 (Aug.) 1948.

Constitutional resistance and the development of antibodies are important factors in any form of disease, often determining whether a treatment results in success or failure. Since virus infection apparently inhibits the cellular elements required to combat streptococci, a streptococcic infection will be much severer, and in some cases even fatal in the presence of a virus.

Nutritional deficiencies also contribute to loss of constitutional or cellular resistance. Lack of folic acid (pteroyl glutamic acid) and other vitamins, for example, will lower the resistance, as shown in experiments with monkeys. The spleen also plays an important role in the body's defense, being a reservoir for blood cells and a conservator of and storage depot for the basic materials from which the continuous new supply of blood cells must come.

HITSCHLER, Philadelphia.

USE OF A NEW ANTIHISTAMINIC COMBINATION IN THE TREATMENT OF ALLERGIC DISORDERS. EARL B. BROWN AND FREDERICK W. BROWN, New York State J. Med. **48**:1465 (July 1) 1948.

This survey of 121 cases was made under the auspices of the Committee on Therapy of the American Academy of Allergy. The authors assume at the outset that an antihistamine drug is accepted as useful in allergic conditions. But there have been disturbing side reactions, namely drowsiness, nausea, "heartburn," shakiness, dizziness, gastrointestinal symptoms, dryness, wheezing and spasm of the salivary duct. A new chemical combination of aminophylline U. S. P. and diphenhydramine hydrochloride (hydryllin®) gives some hope of overcoming these objections. One tablet (25 mg. of diphenhydramine hydrochloride) was given three or four times daily after meals and was increased as necessary, but not more than 8 tablets were given daily. Of 97 patients, 80 per cent showed definite improvement. Of the adult patients with asthma 82 per cent showed improvement.

Side effects were notably reduced as compared with those occurring with diphenhydramine hydrochloride used alone.

VOORHEES, New York.

News and Comment

COURSE IN OTOLARYNGOLOGY, WASHINGTON UNIVERSITY SCHOOL OF MEDICINE

An eight month's course in otolaryngology will be given by the Washington University School of Medicine from Oct. 3, 1949 to June 1950.

Further information may be procured from the assistant dean, Dr. Merl J. Carson, Saint Louis 10.

COURSE IN CLINICAL AUDIOMETRY, STATE UNIVERSITY OF IOWA COLLEGE OF MEDICINE

An intensive two week course in clinical audiometry will be offered at the State University of Iowa College of Medicine, from June 14 to 28, 1949. The course will be conducted daily from 8 : 00 a. m. to 5 : 00 p. m. and will include lectures on audiometry, lip reading, speech training for the hard of hearing, psychologic problems of the acoustically handicapped and clinical otolaryngology; laboratory work, including observation on and participation in hearing testing and hearing aid fittings for clinical patients in the Department of Otolaryngology and Oral Surgery, State University of Iowa Hospital; observation of the university's comprehensive speech pathology program, and special lectures and demonstrations by Prof. John S. Steinberg, of the Bell Telephone Laboratories, and Mrs. Bernice Rutherford, of the Rehabilitation Center, St. Paul.

One of the Iowa Hearing Clinics, concerned with the medical, psychologic, speech, audiometric and social work approaches to cases assembled by the Department of Otolaryngology and Oral Surgery, the Iowa State School for the Deaf, and the Speech Clinic, will be scheduled during the intensive course.

For further information, address Prof. Wendell Johnson, Director, Speech Clinic, State University of Iowa, Iowa City.

Book Reviews

Oral Anatomy. By Harry Sicher, M.D. Price, $15. Pp. 500. St. Louis: The C. V. Mosby Company, 1949.

This book is written especially for the dental student to supplement books on human anatomy which are more detailed and cannot devote space to allied subjects. It accomplishes much in bridging the gap between theory and practice by emphasizing the anatomic basis for many practical procedures used by dentists and oral surgeons.

It has two major sections: one, on the usual descriptive anatomy, stressing structures closely allied to work in dentistry; the other, on regional and applied anatomy. The latter section is excellently written and explains practical procedures on an anatomic basis, so that the student no longer has to follow fixed methods but can evolve his own by understanding the anatomic reasons for them. There are numerous fine pictures and diagrams depicting clearly the author's intentions. Several sections are exceptionally worth while to the otolaryngologist; these concern the temporomandibular articulation, local anesthesia and the ligations of the vessels in the head and neck. This book supplies important information in a clean, concise and simple manner.

A Concise Clinic of Ear, Nose and Throat Diseases. By Erhard Lüscher, Professor of Ear, Nose and Throat Diseases and Director of the University Clinic of Ear, Nose and Throat Diseases, Basel, Switzerland. Cloth. Price, 54 francs. Pp. 513, with 201 illustrations, many of which are colored. Basel, Switzerland: Benno Schwabe & Company, 1948.

This book was written primarily for the student and the general practitioner. The matter is admirably presented, concisely, and yet every important phase of otorhinolaryngology is covered. The work is divided into three parts. The first part deals with the anatomy and the physiology of the ears, the nose and the throat. The second part is devoted to a detailed description of various methods of examining the ears, the nose, the throat and the larynx, and this description is graphically supplemented by many photographs and a careful detailed report of the normal findings. The third part deals with pathologic conditions. Each disease is described from the standpoint of cause, symptoms, course, physical findings, diagnosis, treatment and prognosis. Emphasis is placed on medical and conservative treatment, and the role of the antibiotic substances and the sulfonamide compounds is evaluated. Surgical intervention, where indicated, is discussed briefly—more or less in outline form.

The entire subject is clearly and succinctly presented, in logical sequence, and this makes extremely easy reading. Although the book was intended primarily for the student and the general practitioner, it has real value for the specialist.

Directory of Otolaryngologic Societies *

INTERNATIONAL

FOURTH INTERNATIONAL CONGRESS OF OTOLARYNGOLOGY

President: Dr. V. E. Negus, London, England.
General Secretaries: Dr. F. C. W. Capps and Dr. W. A. Mill, 45 Lincoln's Inn Fields, London, W. C. 2.
Place: London. Time: July 18-23, 1949.

SECOND PAN-AMERICAN CONGRESS OF OTO-RHINO-LARYNGOLOGY AND BRONCHOESOPHAGOLOGY

President: Prof. Justo Alonso.
Secretary: Dr. Chevalier L. Jackson, 255 S. 17th St., Philadelphia 3.
Place: Montevideo. Time: January 1950.

NATIONAL

AMERICAN MEDICAL ASSOCIATION, SCIENTIFIC ASSEMBLY, SECTION ON LARYNGOLOGY, OTOLOGY AND RHINOLOGY

Chairman: Henry B. Orton, 224 Delavan Ave., Newark, N. J.
Secretary: Dr. J. Milton Robb, 1553 Woodward Ave., Detroit, Mich.
Place: Atlantic City, N. J. Time: June 6-10, 1949.

AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

President: Dr. Conrad Berens, 35 E. 70th St., New York.
President-Elect: Dr. J. Mackenzie Brown, 1136 W. 6th St., Los Angeles 14.
Executive Secretary-Treasurer: Dr. William L. Benedict, 100-1st Ave. Bldg., Rochester, Minn.

AMERICAN BRONCHO-ESOPHAGOLOGICAL ASSOCIATION

President: Dr. Paul Holinger, 700 N. Michigan Ave., Chicago 11.
Secretary: Dr. Edwin N. Broyles, 1100 N. Charles St., Baltimore.
Place: Drake Hotel, Chicago. Time: April 18-20, 1949.

AMERICAN LARYNGOLOGICAL ASSOCIATION

President: Dr. Frederick T. Hill, 177 Main St., Waterville, Maine.
Secretary: Dr. Louis H. Clerf, 1530 Locust St., Philadelphia 2.
Place: Biltmore Hotel, New York. Time: May 16-17, 1949.

AMERICAN LARYNGOLOGICAL, RHINOLOGICAL AND OTOLOGICAL SOCIETY, INC.

President: Dr. John J. Shea, 1018 Madison Ave., Memphis, Tenn.
Secretary: Dr. C. Stewart Nash, 708 Medical Arts Bldg., Rochester 7, N. Y.
Place: Drake Hotel, Chicago. Time: April 18-20, 1949.

SECTIONS:

Eastern.—Chairman: Dr. Harold G. Tobey, 403 Commonwealth Ave., Boston.
Southern.—Chairman: Dr. Watt W. Eagle, Duke University, Durham, N. C.
Middle.—Chairman: Dr. Dean M. Lierle, University Hospital, Iowa City.
Western.—Chairman: Dr. Leland G. Hunnicutt, 98 N. Madison Ave., Pasadena, Calif.

AMERICAN OTOLOGICAL SOCIETY

President: Dr. Marvin F. Jones, 121 E. 60th St., New York.
Secretary: Dr. Gordon D. Hoople, Medical Arts Bldg., Syracuse 3, N. Y.
Place: Biltmore Hotel, New York. Time: May 18-19, 1949.

AMERICAN OTORHINOLOGIC SOCIETY FOR THE ADVANCEMENT OF PLASTIC AND RECONSTRUCTIVE SURGERY, INC.

President: Dr. Samuel F. Kelley, 47 E. 61st St., New York 21.
Secretary: Dr. Norman N. Smith, 291 Whitney Ave., New Haven 11, Conn.

AMERICAN SOCIETY OF OPHTHALMOLOGIC AND OTOLARYNGOLOGIC ALLERGY

President: Dr. Rea E. Ashley, 384 Post St., San Francisco.
Secretary-Treasurer: Dr. Joseph Hampsey, 806 May Bldg., Pittsburgh 22.

* Secretaries of societies are requested to furnish the information necessary to keep this list up to date.

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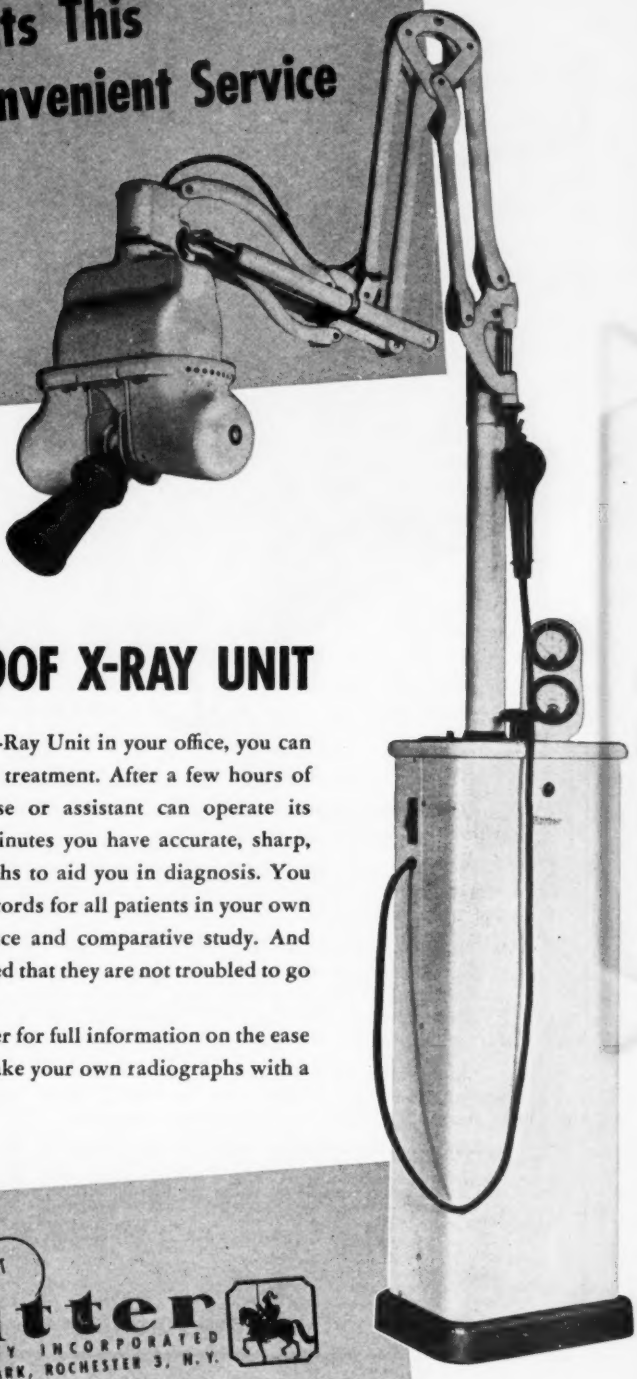

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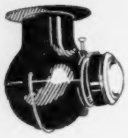

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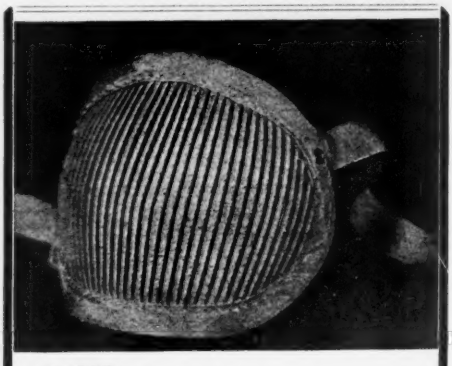

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REARDON, W. T., ARCHIVES OF OTOLARYNGOLOGY, MARCH 1947: 294-297

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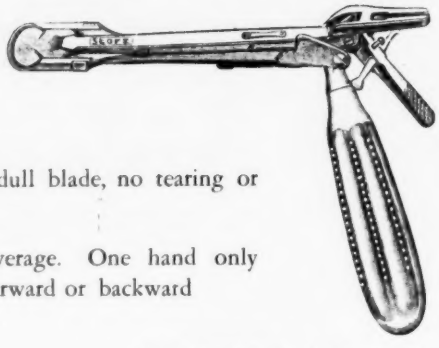

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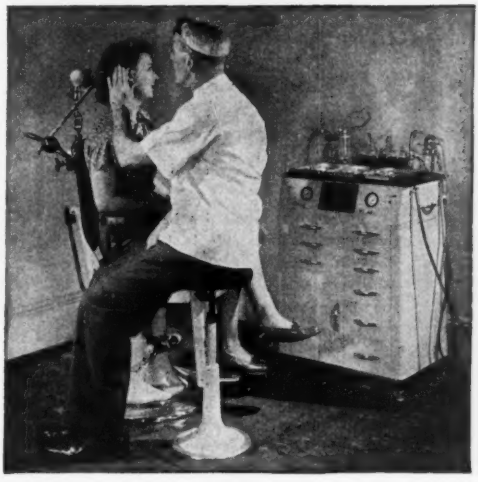

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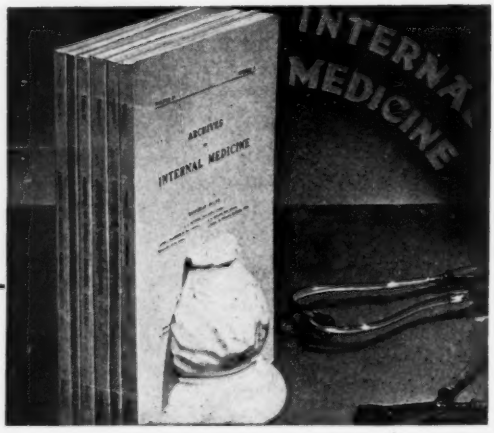

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